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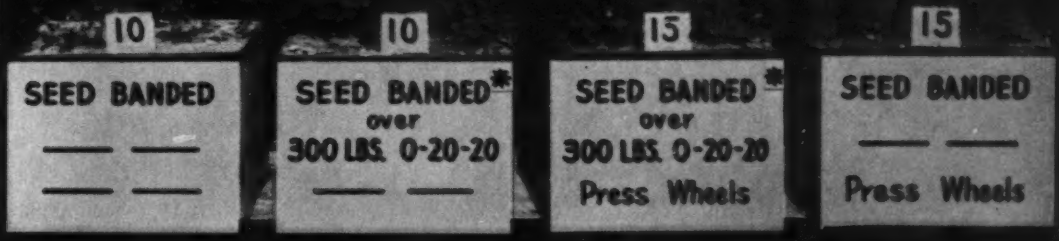
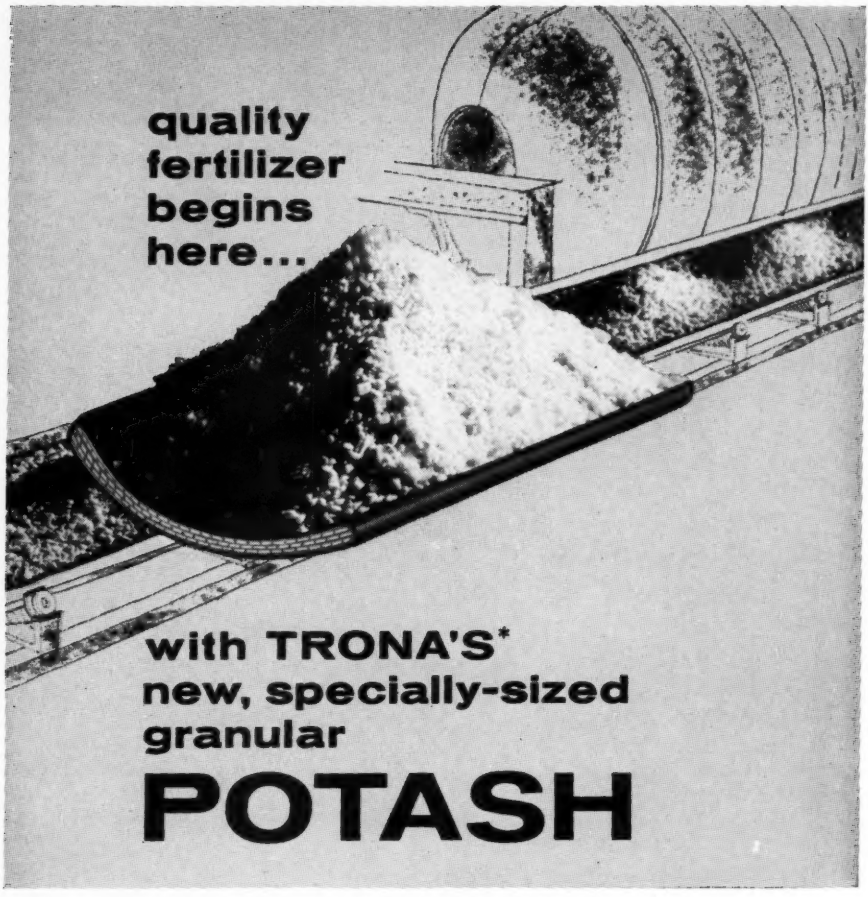


PRESS WHEELS + FERTILIZERS BOOST ALFALFA STANDS



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ON THE COVER . . .

. . . experiments on band seeding alfalfa show how properly placed fertilizer beneath seed rows gives roots and tops more vigorous early growth—and how press wheels following fertilizer applied by a band seeding drill give the seed shallow planting but closer contact with moist soil, causing quicker germination, faster early growth, and a better stand.

In his article starting on page 6, John L. Parsons of the Ohio Agricultural Experiment Station shows how band seeding alfalfa in late summer gives the seedlings a better chance to get a vigorous start before winter comes.

In the top picture, we see that seeding with press wheels on the drill gave *50 per cent more plants,* while fertilizers boosted top growth. Here are 1-foot lengths of 7-week-old alfalfa from differently seeded plots. The numbers, 10 and 15, are the average numbers of seedlings that survived each foot of row.

In the bottom picture, the same plants appear with all soil washed from their roots. Banding the seed alone (left) did not cause good growth. Banding seed plus press wheels (right) produced a better stand but scarce feeder roots and stunted top growth. The best uniform growth came from press wheels following fertilizer applied by a band seeding drill (third from left). Notice the line of expanded feeder roots in the fertilizer band area.

Better Crops WITH PLANT FOOD

The Whole Truth—Not Selected Truth

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They'll always be . . .

PATCHING UP PARITY

Jeff McDermid

(ELWOOD R. MCINTYRE)

One of the anecdotes told by the USDA bulletin dispensers concerned a mysterious lot of requests for the circular, "The Party Handbook." Culinary ladies in the home economic realms disavowed any such authorship. Finally, an astute delver in the "figure foundry" ventured that the word in question was "parity." In a broad sense it *was* a sort of party handbook, since the spokesmen of both major parties keep the word in stock for rural campaign rallies.

Even so, the ditty goes: "That farmer is a rarity who can tell you what is parity." As economists would tell it, "This tends to implement a chaotic condition in the mental processes of the bucolic clientele it is designed to liberate and stabilize." In our own language, "Parity figuring is over the heads of most farmers and at least half of our Congressmen, without going any higher out of extreme respect."

But is that so bad? Very few of us can explain the intricacies of everyday accepted things. We just know they work or don't work. We usually rely on experts to make, repair, or adjust these modern marvels.

Farmers know how to run tractors, but they are not often able to tell all there is to know about power steering, fast hitch, hydraulic lifts, torque amplifiers, and multiple transmission.

They use tons of 2, 4-D to kill weeds in their corn fields, but ask one of them the meaning of "dichlorophenoxyacetic acid" and he will order you off the place for swearing.

Weak understanding of the formulas that supposedly make parity work is hardly the main fault we pick with it. Don't forget we have a new generation of trained men on our farms. Formula farming and formula feeding will rule in the present and the future. So why not the parity formula, too?

To our erudite young men on farms, a parity formula is just another complex proposition, subject to analysis, deliberation, and debate. We also know too well that the beginning farmer today faces a set of harsh financial questions. He has a farm to buy or rent, as well as stock and equipment to get, based on a scale of values in *1958 money* undreamed of when parity first got hooked to the farm program.

As a student he studies parity academically. But as a responsible farm operator with a mortgage to plow under, he may change his mind. If he is a renter, will he agree with his landlord that he must stand on his own feet forever and forget the nonsense about government loans and all the rest of it? Will he be willing to abolish the whole caboodle of controls and trust himself regardless of inflation, deflation, drought, or debt?

In short, will our beginning farmer wish to live always as a true rugged individualist, knowing full well what parity is and what is claimed for it?

Another criticism of parity is that it has been changed and monkeyed with so often. I do not get lathered up much on that score. Before berating this as a bad thing I'd hush up and look back again at the old homestead and the swiftly changing scene it occupies. For nearly everything in rural life has been shifted so fast and so often in the past 30 years it makes your head dizzy. Our farm education points with alarm and lament to the status quo.

Step into any up-to-snuff country store. Ask for a set of work harness, a walking plow, a seed corn drying rack, a churn, straw hats for horses, a wood burning range, a windmill, a grain cradle, and a hot-water chick incubator. No chance. See the historical museum. But they'll have tractors and trucks, implements of new design, and shelves crowded with technical-termed pesticides, fungicides, herbicides and fertilizers. It all moves ahead with the new needs and conditions in agriculture.

Peek and Johnson and other McNary-Haugen bill supporters first used the parity concept as between prices of farm and nonfarm products. Congress has altered the parity system in successive years. These involved basics and non-basics, changes of base periods from pre-war to post-war years; adoption of moving averages for 10-year periods prior to the year of reckoning; use of adjusted price formulas to get modernized parity; addition of taxes, interest, and farm wages to the index; the new transition period of reduced parity on basics; and the flexible scale of supports between 75 and 90 percent of parity.

Out of an older system of special "farm ratio" prices estimated over a long series of years, the original parity formulas were evolved to determine support price levels to qualified farmers. Note that Secretary

Benson regards these long-existent parity ratios and indexes as merely analytical devices to measure farm price trends and changes up and down, as well as relation between prices farmers get and prices they pay. He does not consider them reliable for laying down programs to secure farm stability and prosperity.

That's one way to look at the problem, but Congress may be slow to accept such a sudden parting with parity, unless something as good or better can be trotted out of the economists' bag of tricks.

Yet, it seems critics of parity are pretty well fortified with material to offer. They see a few cracks in the parity structure which they aver could make it crumble, such as these:

Parity prices under any calculation cannot insure farmers equitable income, either individually or collectively. Parity prices do not determine the level at which competition can be successfully met. Domestic prices based on parity standards often price goods out of the foreign markets. Parity prices do not determine how much or how little farmers will raise. Low supports as well as high ones can result in an increased output. Administratively feasible and financially supportable programs are hard to work successfully on a fixed formula basis. Farm prices held at or near parity in a general depression could put agriculture in a favored spot, causing the public to resent all government action. Parity prices must not be confused with a "normal" or a "necessary" price. Parity price as now defined will often bring on more output than can be sold at that fixed price.

Meanwhile, there exists a worldwide urge to increase food crops. Many nations abroad have used higher prices to farmers on a guaranteed basis to secure a bulge in output. Along with it they have put on new and stiffer import controls to bar out cheaper outside surpluses.

This means our farmers must cut the cloth of contemplated plans down to a size we can live with here without penalizing the efficient producer unduly. Consumers begin to see at last that high retail prices for many foods result mainly in giving employment and good wages to some of their own neighbors in the food industry. The old cry of "farm profiteering" begins to fade away—as it should.

Those who think a dwindling ratio of farm workers to total population of voting age spells defeat and dirty work at the old rural crossroads are just vague alarmists. The strength and influence of our skilled and strategically located food producers will always provide them with reserved seats among the mighty. They may not need to holler and snap their suspenders and splash tobacco juice in the eyes of the opposition. Other more subtle and effective ways will maintain the supremacy of farming and the integrity of our agricultural regions.

All in all, boys, we often find ourselves in respect to parity ratios and reasoning somewhat like that old farmer whose oxen ran away before he could yoke them to a loaded cart. Wiping his brow, he remarked:

"It just ain't no use going to town without something strong like that to hitch up to! So I reckon we'll have to eat them potatoes ourselves."

◄◄◄

BAND SEED ALFALFA

Figure 1—Drills with front-mounted legume seed boxes can be converted to do band seeding by attaching special tubes to carry seed back behind disc openers. Pack wheel attachments are also available.

By J. L. Parsons **Department of Agronomy**

BAND seeding reduces the risks of summer seeding alfalfa. Because of this, present research work in Ohio is aimed at improving the band seeding method as a means of establishing alfalfa.

What is Band Seeding?

The term "band seeding" refers to a specific placement of seed and fertilizer by a drill—that is, fertilizer is banded 1½ to 2 inches deep, with alfalfa seed dropped directly over this band but on the surface in the depression left by the disc opener. The addition of press wheels to compact soil over the shallow seeding speeds germination and improves stands, especially in dry periods.

Regular drills can be converted for band seeding by kits with special tubes that carry small seeds from the front to the back of the openers. Press wheels are also available to attach to

Dr. John L. Parsons, forage crop agronomist for the Ohio Agricultural Experiment Station, is a Kansas native. He earned his B.S. and M.S. at Kansas State, his Ph.D at the University of Massachusetts. He has served the Ohio station at Wooster for 5 years.

And to be successful at it . . .

1 *Seed alfalfa shallow in firm, moist soil to get fast uniform germination and a high percentage survival of seedlings.*

Figure 2—Pack wheels compact the soil over the seed and fertilizers, as shown here, permitting upward movement of moisture. This helps start rapid germination and faster seedling growth.

Ohio Agricultural Experiment Station

some drills (Figure 1). Some special drills are now also made to accomplish all placement and compaction requirements.

In Figure 2, we see the condition of the soil surface after it was seeded by a band seeding drill plus press wheels. Note alternate compact and loose areas. The tiny alfalfa seeds were scattered in the groove left by the disc opener. *Then press wheels compacted the soil to enable moisture from below to come up and help start germination. The top root of the new seedling will soon contact the fertilizer band about 1½ to 2 inches below the seed level.*

Moist soil frequently will not flow back into the furrow made by the drill, and the alfalfa seed is dropped in a narrow trench 1 to 2 inches deep. Alfala seeds that germinate in the bottom of an open furrow are subject to siltation and crusting damage for

---

2 *Drop seed behind rather than in front of disc openers, to get a more uniform, shallow seeding.*

3 *Use press wheels behind the seed spouts to compact the soil and permit upward movement of moisture, making favorable germination conditions.*

4 *Place fertilizer in a band safely below the seed level for top efficiency. This does not hinder germination. The tap root of the young seedling soon reaches the plant food, resulting in fast normal growth.*

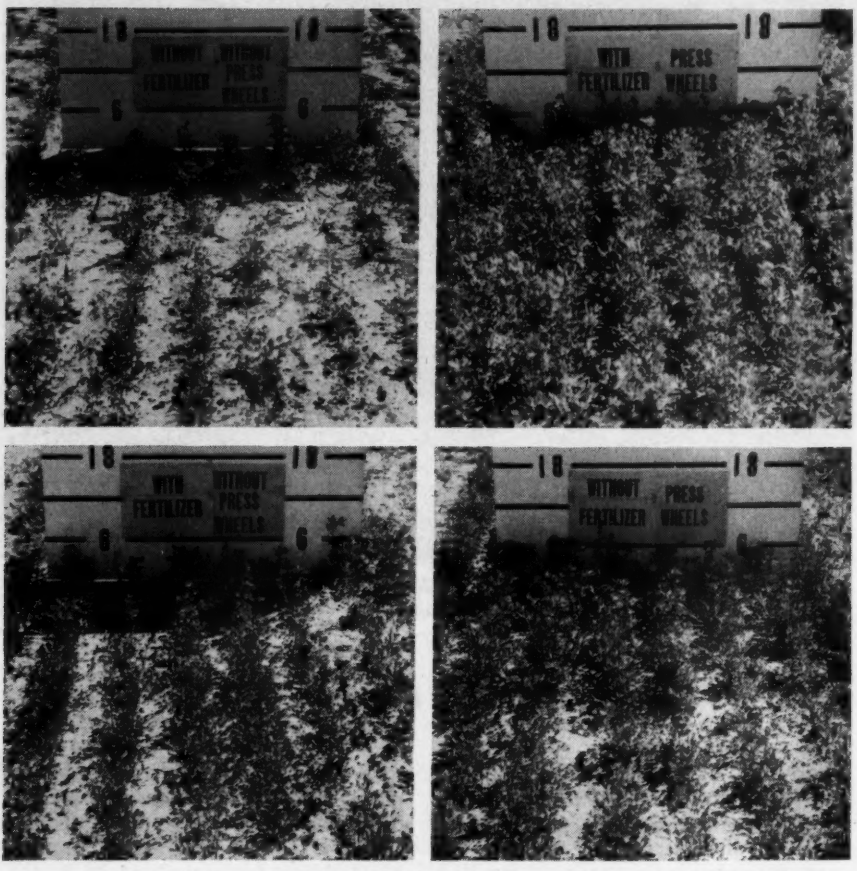


Figure 3—Above is shown 7-week-old alfalfa plants from 4 plots of a band seeding experiment, comparing separate and combined effects of fertilizer and press wheels.

***Top left*—Although it was band seeded, a poor stand resulted *without* fertilizer or press wheels.**

***Top right*—A thick stand of vigorous plants came from band seeding *with* fertilizer and press wheels.**

***Bottom left*—Without press wheels, germination was slow and irregular even though seed was banded over fertilizer.**

***Bottom right*—Without fertilizer, plants were short although there was a good stand.**

several weeks. A short drag chain attached in *front* of the band seeding tube tends to level the furrow. Packing wheels and drag chains used in combination with band seeding do much to improve summer seedings.

Research Results

Ohio research results are shown in Figure 3, which shows how band seeding is effective when properly done.

Also, the two cover pictures illustrate (1) how press wheels improve stands, (2) that fertilizers boost early growth of roots and tops.

Figure 4 shows 7-week-old alfalfa plants from one foot of row from plots with and without fertilizer. Note how feeder roots *expanded along the fertilizer band.* Deeper roots also were more vigorous when fertilizer was applied.

Summer seeding of alfalfa has several advantages:

Left—300 lbs. 0-20-20 banded **Right—No fertilizer**

Figure 4—Notice here the expanded feeder roots along fertilizer band and generally larger root system. Both plots were band seeded with press wheels.

1. Better stand. The farmer who has stand failures from broadcasting a mixture of alfalfa and red clover on wheat land in the spring will be amazed at his first successful experience with summer seeding of alfalfa. Instead of having a meadow crop in which the legume is predominately red clover, he will have a meadow crop that is entirely alfalfa or a mixture of alfalfa and grass.

2. Weed free stands. By seeding in August weed competition is avoided because very few weeds germinate and become a nuisance in the summer.

3. Efficient application of lime and fertilizer. Lime applied before starting seedbed preparation mixes thoroughly with the surface soil in a manner that will do the alfalfa seedlings the most good. Corrective applications of phosphates or potash can be applied ahead of seeding, but the fertilizer band directly beneath the row, yet not in contact with the weeds, is *the key* to the fast growth of seedlings.

A third advantage of summer band seeding is the opportunity to apply lime and fertilizer in a manner that will do the alfalfa seedlings the most good. When lime is applied before starting seedbed preparation, it gets mixed thoroughly with the surface soil. Corrective applications of phosphates or potash can be applied ahead of seeding, but the fertilizer band directly beneath the row, yet not in contact with the seeds, is the key to fast growing seedlings.

High Yields

Hay yields are the true test of summer seeded alfalfa. Ohio tests have shown first year hay yields from summer seedings are sometimes just as high as yields obtained by any other seeding method. Frequently the hay obtained contains *fewer weeds* and *more alfalfa.*

Alfalfa band seeded in August 1955 produced 2.14 tons per acre the following year, while alfalfa band seeded in oats in spring 1955 produced 2.02

Figure 5—The contrast in discing and plowing shows what different seedbeds the two methods can provide—illustrated above and described below.

Above—Discing wheat stubble only twice produced an excellent seed bed. The surface is fine and compact. Soil moisture just beneath the surface is ready to start alfalfa seedlings. Grain stubble residues help prevent damage from siltation and crusting.

Above—Plowing at the same time left a rough seedbed. Discing 3 times plus cultipacking did not sufficiently reduce the size of clods. It is doubtful whether a good stand can be obtained in such a dry, loose, cloddy seedbed.

tons per acre. A similar comparison in 1957 saw summer seedings equal spring band seedings in oats in the first hay crop. *Attempts to compare yields of summer seedings with spring broadcast seedings in wheat are frequently unsuccessful because of complete failure of the spring seedings.*

Seedbed Preparation

A firm, moist seedbed is the key to successful summer seeding of alfalfa. Quick germination and rapid growth of the alfalfa seedlings are the main objects.

Immediately after wheat harvest, remove the combined straw and start the tillage. If soil tests indicate a need for lime or more fertilizer than can be applied in the row, these can be added before tillage begins.

Discing Best

Discing is the only tillage necessary for preparing the seedbed in many cases. This leaves a firm seedbed with good moisture relations, incorporating the wheat stubble into the surface soil. A thunderstorm is one of the curses of a summer seeding. Wheat stubble incorporated by discing helps to prevent erosion and surface crusting.

The two pictures in Figure 5 show how discing often prepares a more satisfactory seedbed than plowing, under certain soil conditions.

A mulch of strawy manure applied immediately after seeding is desirable where the seedbed has been plowed. If the mulch material is not available at this time, however, then apply 4 or 5 tons per acre of strawy manure in November or December.

Kill Volunteer Wheat

Volunteer wheat may damage alfalfa seedlings by competition in the fall, and be a problem in the first hay crop.

Volunteer wheat that germinates usually can be killed with a couple of discings about two weeks apart if started early. Plowing frequently eliminates the volunteer grain problem but creates a seedbed that is loose and subject to erosion and crusting. Shallow plowing is best when using this

method of seedbed preparation. Sloping land should not be plowed at this season of the year.

There is no known satisfactory way to control volunteer grain after the summer seeding is made. Current research in Ohio is using chemical herbicides for the control of severe infestations of volunteer grain. Harvesting early in the spring for grass silage is a good way to use a meadow crop that has a large amount of volunteer grain.

Rate of Seeding

Rate of seeding is the same for summer as for spring seeding. The recommended rate of seeding alfalfa in Ohio is 10 pounds per acre when seeded alone and 4 to 8 pounds when sown in mixtures.

Grain crops should never be used with summer seedings. The competition for water more than offsets any advantages of a companion crop.

Legumes other than alfalfa should not be used in an August seeding. Red clover usually does not produce satisfactory growth for successful establishment from an August seeding. Birdsfoot trefoil produces a very slow growth in the seedling stage and frequently does not establish successfully when seeded after August 1 in Ohio.

Alfalfa-grass mixtures. Bromegrass and timothy usually establish well with alfalfa in an August seeding. Bromegrass should be seeded at 6 pounds per acre and timothy at 1 to 2 pounds per acre.

Get 5 to 7 Weeks Growth

Alfalfa seedlings require 5 to 7 weeks of growing weather to become well established. In northern Ohio, this means planting before September 1. September 15 is considered the latest safe date for a summer seeding in southern Ohio. The earlier you seed alfalfa the better chance you give it to become established before winter.

Never graze or clip a summer seeding of alfalfa in the fall. All leaf surface must be retained for the contribution that it will make to the plant food reserve in the roots.

Better Equipment and Methods

We still need more research toward building the best equipment for seeding forage crops. Progress is being made. Meanwhile, farmers will do well to adapt the principles proved most satisfactory in seeding method trials to date.

A summary of conclusions drawn from previous experiments might include:

1. *Seed alfalfa shallow in firm, moist soil to get fast uniform germination and a high percentage survival of seedlings.*
2. *Drop seed behind rather than in front of disc openers, to get a more uniform, shallow seeding.*
3. *Use press wheels* behind *the seed spouts to compact the soil and permit upward movement of moisture, making favorable germination conditions.*
4. *Place fertilizer in a band safely below the seed level, for top efficiency. This does not hinder germination. The tap root of the young seedling soon reaches the plant food, resulting in fast normal growth.*
5. *Band seed with the above principles for most successful summer seeding of alfalfa.*

◄ ◄ ◄

On Roots . . . As Well As Tops

"Future plant breeders may have to breed varieties with a capacity to utilize still larger quantities of nutrients in a short season if we expect to boost yield goals much higher. Perhaps more attention should be focused on roots of plants as well as the tops."

—Herbert L. Garrard.

FERTILEGRAMS

Average yields of *eighteen tons per acre of corn silage* have been obtained at the Experimental Farm, Nappan, Nova Scotia, from a combination of ten tons of manure and *350 pounds of 6-12-12 fertilizer.*

These results, says E. T. Goring, agronomist at Nappan, were obtained in an experiment in which fertilizer formula, rates of application and combinations of fertilizer and manure were compared over a nine year period.

In the test of formula the 1-2-2 ratio has proved as satisfactory as any on the clay loam soil at Nappan and is readily available in the form of 6-12-12.

~

It takes a lot more than sunshine to grow 100 bushels of corn. A few of the requirements are:

420,000 gallons of water per acre.

160 lbs. of nitrogen, 60 of phosphate and 120 of potash.

16,000 corn plants per acre.

~

Alfalfa is considered the top forage crop in the United States, says O. N. Andrews, Alabama Polytechnic Institute Extension feed and grazing crops specialist.

This crop will do more good for dairy cows and hogs than any other crop, he says. Alfalfa hay will produce milk—which is important in both dairy and beef animals—where most other hay crops act only as a filler, he points out.

Andrews said H. Haskell Lumpkin, Lamar County agent, reports farmers in his area have received as much as *six pounds of milk daily increase per cow* when alfalfa hay was added to the ration.

Swine producers, said Lumpkin, have reported that *feeding costs* for topping out hogs were *reduced as much as 40 percent* when hogs were on alfalfa grazing.

Several Lamar County farmers harvested as much as four tons of hay per acre from their alfalfa last year, said the agent, and have already made one cutting of more than a ton per acre this year.

Andrews suggested farmers who have land in the acreage reserve of the Soil Bank prepare the land this summer *to seed alfalfa in September.* This is a good summertime job, and alfalfa will be ready for grazing in January.

Local ASC offices will pay about 50 percent of the cost of planting alfalfa, Andrews reminded. This includes the lime, fertilizer, and seed.

If you have a need for alfalfa on your farm, this is a good year and opportunity to get it established.

~

Limestone, phosphate and potash each contributed its share toward raising 1957 corn yields on Dixon Springs Experiment Station plots from 8 to 75 bushels an acre.

Lowest yield of only 8 bushels an acre was on untreated land, says Lee Gard, University of Illinois Station researcher.

Plots treated only with limestone have had 8 tons an acre applied over the past 20 years. The 1957 corn

from Across the Land

FOR BETTER SOILS • FOR BETTER CROPS

yield on these plots was 37 bushels an acre. This 29-bushel an acre increase for limestone alone resulted from an annual cost of only $1.30 an acre, Gard points out.

Annual addition of *100 pounds of muriate of potash* on limed land at a cost of $2.50 increased corn yields *another 13 bushels* for a yield of 50 bushels an acre.

Putting on 100 pounds of 20% superphosphate at a cost of $2 an acre increased corn yields on limed land 33 bushels for a total yield of 70 bushels an acre.

Last year's corn yield was 75 bushels an acre *where limestone, phosphate, and potash were added together at an annual fertility cost of $5.80 an acre.*

Most farmers will need a corn yield of at least 40 to 50 bushels an acre to "break even" under today's high costs of production, Gard believes. Lime alone is essential, he points out, but a combination works out best in most cases.

~

Research at the Kentucky Agricultural Experiment Station shows that *balanced fertilization* is needed to produce satisfactory yields on a 3-year corn-wheat-red clover rotation.

In the Kentucky tests, plots getting *lime only* produced 11 bushels of corn per acre, .7 of a bushel of wheat, and .4 of a ton of hay.

Plots that got *phosphorus only* yielded 52 bushels of corn, 16 bushels of wheat, and .6 of a ton of hay per acre.

Plots that got *lime and phosphorus combined* produced 20 bushels of wheat, 1 ton of hay, and for no apparent reason corn yields dropped off.

Plots getting *lime, nitrogen, phosphorus, and potash* produced *66 bushels of corn, 25 bushels of wheat, and 1.7 tons of hay per acre.*

~

Recent research findings by the University of Minnesota show that fertilized pastures can nearly cut in half the amount of grazing land needed for young dairy heifers.

Since the Minnesota experiment began in 1955, the fertilized pasture areas received 60 pounds of nitrogen and 40 pounds each of phosphate and potash each spring, plus 33.5 pounds of nitrogen top-dressing per acre in the summer, plus 4 tons of lime per acre the first year.

There was no difference in the amount of pasture used by identical groups of heifers on fertilized pasture compared to unfertilized areas in 1955. But in 1956, those on the fertilized pasture required only 62 percent as much area as did heifers on unfertilized grass, and last summer it took twice as much area to feed the heifers on unfertilized pasture.

The Minnesota researchers also report that in 1957, the daily gains of heifers on fertilizer pasture averaged .94 pound compared to .64 pound on the unfertilized area. The fertilized pasture is also reported to have produced 436 pounds of heifer gain per acre in 1957, compared to only 148 pounds per acre on unfertilized.

In Georgia's Coastal Plain Area

■ Where potash fertilization increased the yield of all crops studied in an 8-year experiment on a Norfolk sandy loam soil.

■ Where the beneficial influence of potash was much more marked during the last 4 years than the first 4 years.

■ Where one application of 120 pounds of potash per acre to a critically low potash soil *increased corn yields by 54 bushels an acre* over a minus-potash treatment—with an estimated return of $10 for every $1 spent for potash.

■ Where potash application by the average South Georgia farmer is *not adequate* to correct low potash soil conditions.

■ Where the best way to correct critically low potash soils is to broadcast *100 to 200 pounds K_2O an acre* and then *follow fertilizer recommendations through soil tests.*

■ Where it takes *only 2 to 3 years* of cropping *without adequate potash* to reduce the potassium level of Norfolk soil to a point where *most crops cannot be produced profitably.*

■ Where green manures influence crop production little when *adequate nitrogen* was applied under either plus-potash or minus-potash conditions.

Dr. Ralph L. Wehunt, Georgia University Extension Soils and Fertilizer specialist, played a leading role in Georgia's $200 Million and Intensified Soil Fertility Programs. Formerly a commercial and a research agronomist, he earned his B.S. and M.S. from Georgia, his Ph.D. from Rutgers.

By Ralph L. Wehunt and H. D. Morris

University of Georgia

College of Agriculture

SUCCESSFUL CROP

ONE of the most limiting soil fertility factors in Georgia is *potash.* This problem is especially acute in the Coastal Plain area, as shown by the information in Table I. Over 75 per cent of thousands of soil samples collected in two of the Coastal Plain Provinces tested *low in potash.*

Soils in South Georgia are inherently low in potassium. The area also has a high annual rainfall which has leached the element from the soil.

Dr. H. D. Morris, professor of agronomy at the University of Georgia, teaches and researches in the fields of soil fertility and fertilizers. He earned his B.S. and M.S. from N. C. State, his Ph.D. from Iowa State.

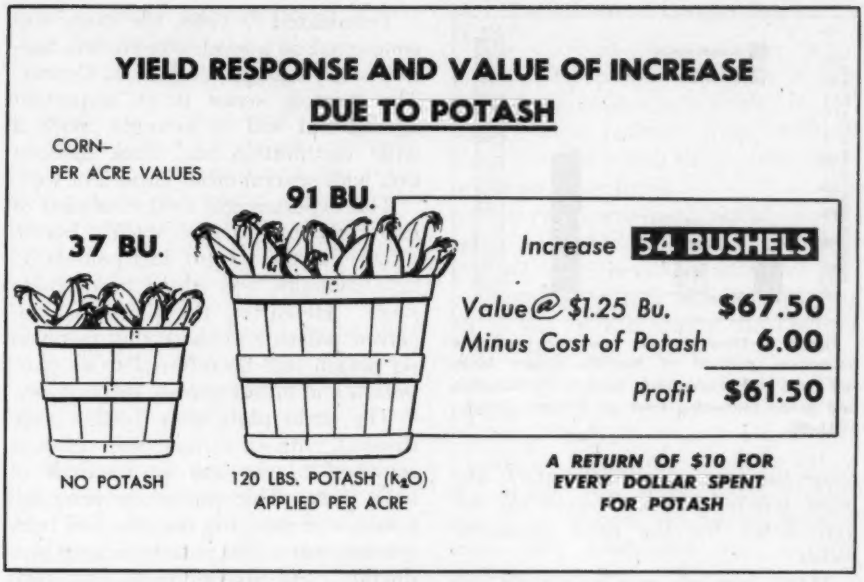


Figure 1—Corn yields are strikingly increased by a single application of potash on Norfolk soils deficient in potassium.

PRODUCTION DEPENDS ON POTASH

Past and present fertility management practices have played a major role in creating low potash soils. Virgin soils in South Georgia are usually lower in phosphate than in potash. However, heavy usage of fertilizers containing a higher phosphate than potash content over an extended period has tended to reverse this situation on cultivated soils.

Also, potassium is more easily leached from the soil than phosphate and plants tend to remove more potassium than phosphate. These factors have caused most of the cultivated land in South Georgia to be medium to high in phosphate and low in potash.

A Critical Problem

These low potash soils present a critical problem in the agriculture of the Coastal Plain area and intensive educational programs are necessary to overcome the dilemma.

More attention must be focused on the important role of potash to assist these farmers in obtaining higher yields and bigger profits.

To alert farmers to the benefits derived from good soil fertility conditions, the Georgia Agricultural Extension Service has launched educational programs in all areas of the state. Also, certain counties have been selected in which intensified campaigns are conducted on soil fertility.

Soil Testing Emphasized

Soil testing is strongly emphasized in these fertility programs. The main objective of the programs is to help farmers use a fertilizer that balances the nutrient supplies in the soils and

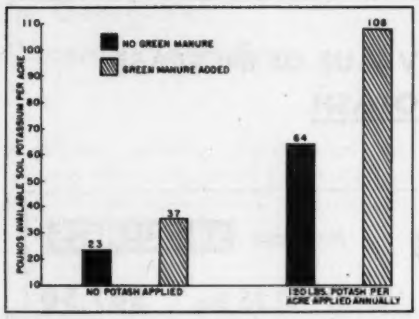


Figure 2—Here we see how the available potassium content of Norfolk sandy loam soil was influenced by potash fertilization and green manuring over an 8-year period—1941-48.

raises the level of all nutrients to the point where they will meet the requirements for the most profitable yields.

Many farmers in Georgia do not use the right kind of fertilizer to balance their soils, as shown in Table II. These data show that inadequate consumption of high-potash fertilizers, such as 5-10-15 and 0-10-20, is limiting crop production.

Potash Field Studies

Realizing the importance of potassium, the University of Georgia Agricultural Experiment Station initiated a field study in 1941 to determine the response of several crops to the element.

Terminated in 1948, the study was conducted on a level, non-eroded Norfolk sandy loam soil in Pulaski County. The Norfolk series is an important agricultural soil in Georgia, with a wide distribution and close association with several other important soils.

The experimental field consisted of *two blocks of 20 plots each.* Potash (K_2O), at the rate of 120 pounds an acre annually, was added to alternate plots. Hereafter, the plots that received potash and those that received no potash will be referred to as *plus-potash* and *minus-potash,* respectively.

The main plots were further subdivided, with all surface crop residues returned to the soil on one-half of each plot. This procedure provided a means of studying the effect of both green manure and potash on crop production. All above-ground crop residues were removed on the other half of each plot. Adequate rates of nitrogen, phosphate, and lime were added to all plots.

Nine summer crops (corn, velvet beans, soybeans, cowpeas, Korean lespedeza, crotalaria, sericea lespedeza, kudzu and Spanish peanuts) and five winter crops (oats, crimson clover, blue lupine, Austrian winter peas and vetch) were grown in the experiment.

All yield measurements were based on an average of two replications each year, except for oats and corn, which

Table I.—Percentage of Georgia Soils Containing Low, Medium, and High Levels of Available Potassium and Phosphorus[1]

Soil Province	Number of samples	Potassium level			Phosphorus level		
		Low	Medium	High	Low	Medium	High
Limestone Valley and Ridge	8,259	49	38	13	49	21	30
Mountain and Intermountain	6,457	43	44	13	53	22	25
Piedmont Plateau	31,234	40	39	21	56	17	27
Upper Coastal Plain	17,276	62	28	10	54	22	24
Middle Coastal Plain	25,707	77	19	4	49	27	24
Lower Coastal Plain	9,501	78	19	3	41	29	30
State Average		58	30	12	52	22	26

[1] Data compiled by Soil Test Work Group Committee of Agronomy Division.

were based on an average of six to eight replications.

Soil Results

At the end of the eight-year study, a composite soil sample was collected from each plot to determine the available potassium content. Results obtained from the analysis are shown in Figure 1. Unfortunately, no tests for soil potassium were made when the study was started.

Soil from the minus-potash plots on which crop residues were removed had reached a critically low level of 23 pounds of available potassium an acre by 1948.

The available potassium content of the plus-potash, green manure plots was 108 pounds an acre—or about five times greater than the minus-potash, no-green manure plots. Even so, after eight years of high potash fertilization, the soil contained only a medium level of available potassium.

Crop residues returned to the soil increased the available soil potassium content of both the plus- and minus-potash plots. (Figure 2).

Potash and Crop Yields

The yield of various crops as influenced by potash additions to the Norfolk soil is shown in Table III. All surface crop residues were removed from plots on which these yield measurements were made.

Without exception, potash fertilization increased the yield of all crops studied. The beneficial effect of potash on the growth of all crops was much less marked during the 1941-44 period than the 1945-48 period of the study. The production resulting from potash additions varied widely within the crops studied. Based on response to potash during the latter period of the study, the crops were divided into three groups—*highly responsive, moderately responsive,* and *slightly responsive.*

Crops highly responsive to potash: Potash fertilization of the first group of crops increased yields by 70 per cent or more over the minus-potash treatments. Five crops—*cowpeas, Austrian winter peas, corn, blue lupine* and *Spanish peanuts*—were classified

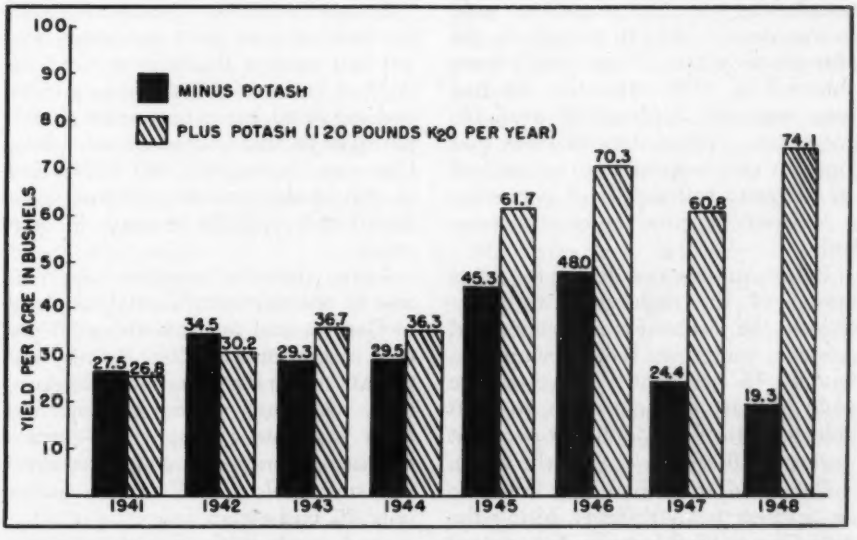


Figure 3—Here we see the effect of potash fertilization and depletion of soil potassium on corn yields over an 8-year period—1941-48. Note how potash influence became much stronger during the last 4 years.

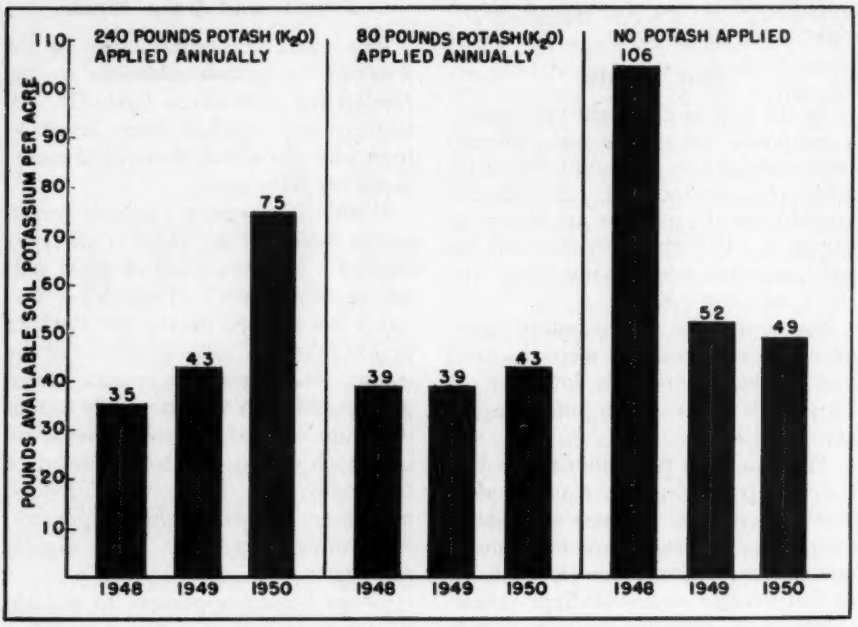


Figure 4—Here we see how the rate of potash fertilization affected the available potassium content of a Norfolk sandy loam soil over a 3-year period. The soil was cropped to corn and crimson clover. And potassium content in 1948 was that present in the soil after the 8-year study—1941-48.

as *highly responsive* to potash.

Blue lupine yield on the minus-potash was only 880 pounds an acre as compared to *22,120 pounds on the plus-potash plots.* These yields were obtained in 1948, after the soil had been seriously depleted of available potassium. These data indicate that lupine is very responsive to potash and an adequate soil supply of potassium is necessary to grow the crop successfully.

Potash applications during the latter period of the eight-year study increased the production of cowpea and Austrian winter pea forage by approximately 75 per cent. However, the yield increase of these crops attributable to potash was only 25 per cent during the first four years of the study.

Potash additions had little influence on Spanish peanut yields during the initial years of the study, but peanut production was increased markedly by potash additions in 1948. *The soil potassium supply had been depleted to a very low level by 1948.*

Potash fertilization greatly increased the yield of corn grain and stover the last four years of the experiment. The yield of grain was 95 per cent greater and stover 81 per cent greater on the plus-potash than minus-potash plots. However, during the first four years of the study, potash additions produced only a slight increase in corn yields.

Corn, which occupies approximately one-third of the total cropland in Georgia and receives about 40 per cent of the total fertilizer, is very important to the state's agricultural economy. Although marked progress has been made in recent years toward increasing corn production, the average state yield is still far too low—only 25 bushels an acre.

And inadequate use of potash is one of the reasons why corn yields are so low in Georgia, especially in the

Table II.—A Comparison of Fertilizer Ratios Needed and Fertilizer Ratios Used in the Soil Provinces of Georgia

Soil Province	Number of samples	Ratios needed [1] Per cent			Ratios used [2] Per cent		
		Even P–K	High P Low K	Low P High K	Even P–K	High P Low K	Low P High K
Limestone Valley and Ridge	7,849	46	19	35	85	15	0
Mountain and Intermountain	5,885	45	25	30	71	29	0
Piedmont Plateau	20,685	42	34	24	66	34	0
Upper Coastal Plain	14,908	53	17	30	79	20	1
Middle Coastal Plain	23,617	52	6	42	85	14	1
Lower Coastal Plain	7,863	45	4	51	89	10	1
State average		48	17	35	79	20	1

[1] Fertilizer ratios needed were compiled from figures supplied by Soil Test Work Group Committee of the Agronomy Division. Examples of even P–K ratios are 4–12–12 and 6–12–12; an example of a high P–low K ratio is 6–12–6; examples of low P–high K ratios are 5–10–15 and 0–10–20.

[2] Fertilizer ratios used were compiled from figures given in the Georgia State Department of Agriculture Fertilizer Tonnage Report for Calendar Year Ending December 31, 1956.

Coastal Plain region. The data in Table III show clearly the need for potash in successful corn production. Because of the economic importance of this crop, the yield results are presented in a different way in Figure 3.

These data show that corn grain production was reduced markedly after cropping for two years without potash. After a two-year period, the difference in yield between the plus-potash and minus-potash plots became greater with each succeeding year. At the end of the eight-year study, the yield on the minus-potash plots was only 26 per cent of that on the plus-potash treatments.

It takes only a few years of cropping with inadequate potash to deplete the available potassium supply of a Norfolk soil to a point where corn production is not profitable. During the last year of the study, the corn yield on the plus-potash was 61.1 bushels an acre greater than on the minus-potash plots.

Fortunately, as shown in Figure 1, it is not too difficult to increase corn yields on a Norfolk soil that contains a low potassium supply. At the end of the eight-year study, the available soil potassium content in the minus-potash corn plots was only 35 pounds an acre. *An application of 120 pounds of potash (K_2O) an acre to these plots in 1949 increased corn yield by 53.4 bushels an acre—or 142 per cent over plots without potash.* This yield increase resulted in a return of approximately *$10 for every $1 spent for potash.*

Corn yields can be increased markedly in a single season by an adequate application of potash to a Norfolk soil which is critically low in potassium.

However, it is not easy to build up the potassium supply of a Norfolk soil after it has reached a critically low level, *unless a heavy application of the element is added.*

Examine the data in Figure 4: When 240 pounds of potash an acre were applied annually to the Norfolk soil and cropped to corn and crimson clover, it required three years to increase the available soil potassium content. An annual application of 80 pounds potash per acre under identical conditions just maintained the avail-

Table III.—Yield of Various Crops as Affected by Potash Fertilization of Norfolk Sandy Loam Soil Over an Eight-Year Period (1941–48)[1]

Crop	Years	Plus-potash 120 pounds potash (K_2O) added per acre	Minus-potash no potash added	Difference in yield due to potash	Per cent yield increase due to potash
Crops highly responsive to potash					
Cowpea	1941–44	18459	14801	3658	24.7
	1945–48	22639	13005	9634	74.1
Austrian	1942–45	25030	20191	4839	24.0
Winter peas	1946–48	12507	7200	5307	73.7
Corn grain	1941–44	32.5	30.2	2.3	7.6
	1945–48	66.7	34.2	32.5	95.0
Corn stover	1941–44	3385	3013	372	12.3
	1945–48	7253	4011	3242	80.8
Blue lupine	1948 only	22120	880	21240	2414.0
Spanish peanuts	1941, 43, 46	940	960	−20	−2.1
	1948	1033	592	440	74.3
Crops moderately responsive to potash					
Vetch	1942–45	27842	24877	2965	11.9
	1946–48	14410	10200	4210	41.3
Crimson clover	1942–45	22053	17242	4811	27.9
	1946–48	15507	11120	4387	39.4
Korean lespedeza	1941–43	6870	6573	297	4.5
	1944–46	16590	12373	4217	34.1
Crops slightly responsive to potash					
Oat forage	1942–45	14732	12833	1899	12.9
	1946–48	11559	9668	1891	16.3
Velvet beans	1941–44	16576	15741	835	5.3
	1945–48	19815	16576	3239	19.5
Soybeans	1941–44	17617	16489	1128	6.8
	1945–48	20182	16661	3521	21.1
Crotalaria	1948 only	19840	17280	2560	14.8
Sericea lespedeza	1943–44	15257	13221	2036	15.4
	1944–46	22480	17640	4840	27.4
Kudzu	1943–45	24298	22146	2152	9.7
	1945–48	30627	26366	4261	16.2

[1] Forage yields are expressed as pounds of green weight, corn yields as bushels and peanut yields as pounds of nuts an acre.

able potassium supply. *On plots that were adequately fertilized with potash over an eight-year period and also cropped to corn and crimson clover, the available soil potassium was depleted to a critical level in only one year without potash fertilization.*

Even the 80-pound-an-acre rate of potash is greatly in excess of that used by the average South Georgia farmer. It is estimated that the average farmer applies only 35 pounds of potash an acre annually in a corn rotation. It would be impossible, then, to counteract low potassium soils with the potash additions used by the average farmer.

Probably the best way to correct

Table IV.—Effect of Green Manuring and Potash Fertilization for an Eight-Year Period on the Relative Percentage Yield of Certain Crops.

Crop	Relative yield in per cent			
	Minus-potash		Plus-potash	
	No green manure	Green manure	No green manure	Green manure
Cowpeas	100	102	147	146
Austrian winter peas	100	98	134	122
Corn grain	100	131	154	152
Corn stover	100	132	152	175
Vetch	100	105	119	125
Crimson clover	100	129	132	136
Korean lespedeza	100	109	121	115
Oat forage	100	111	117	129
Velvet bean	100	108	117	111
Soybeans	100	90	114	97
Average all crops	100	111	131	131

The yield of the minus-potash, no green manure treatment was expressed as 100 per cent and the yields of other treatments were calculated using 100 per cent as a base.

low potassium soil conditions in South Georgia is to broadcast 100 to 200 pounds of potash an acre and thereafter maintain a medium potassium level by following fertilizer recommendations through systematic soil testing.

Crops moderately responsive to potash: Yields of the second group of crops, classified as moderately responsive to potash, were increased 30 per cent or more by potash additions during the last four years of the study.

The yield of vetch was 41 per cent; crimson clover, 39 per cent; and Korean lespedeza, 34 per cent greater on the plus-potash than the minus-potash plots, respectively.

Also, similar to the crops highly responsive to potash, *the effect of potash fertilization was less marked during the initial than the latter period of the study.*

These data further reveal that the yield of certain crops can be drastically reduced when the soil potassium supply is allowed to become low.

Crops slightly responsive to potash: Potash additions to the third group of crops produced yield increases of less than 30 per cent more than the minus-potash plots. Six crops—oats, velvet beans, soybeans, crotalaria, sericea lespedeza, and kudzu—were classified as slightly responsive to potash.

The influence of potash on these crops was again more marked *during the latter* than the early stage of the study.

Value of Green Manure

The effect of green manure on the yield of several crops under plus-potash and minus-potash conditions is shown in Table IV.

The minus-potash, no-green manure treated crops were assigned a value of 100 per cent, and percentage values were assigned to other crop treatments using 100 per cent as a basis for calculation.

The return of crop residues to the Norfolk soil had little beneficial influence on the yield of most crops studied under either plus-potash or

minus-potash conditions. The beneficial influence of green manure was more apparent for certain crops under minus-potash than under plus-potash treatments. Corn yields were increased more by green manure than any other crop studied. Green manure tended to decrease the yield of Austrian winter peas and soybeans.

These long-term data indicate that green manuring has little value as a soil management practice to increase crop yields in the southern part of Georgia when adequate commercial nitrogen is applied.

Crop residues under ordinary conditions supply most of the organic matter to soils in South Georgia. Green manure crops are valuable as a means of holding the soil in place and for other supplemental values.

They should not, however, be considered as essential in a fertility program as are certain other practices, such as application of adequate plant nutrients.

Inadequate use of potash is a serious factor that is limiting crop production in the Coastal Plain region of Georgia. More farmers should follow fertilizer recommendations based on soil tests to correct low potash soil conditions. Only by taking advantage of all known improved practices can farmers surmount the obstacles they face today in efficient crop production. ◄◄◄

"IN THE BIG HOUSE . . . AND GOOD CAR"

Without fertilizers, this growing world population would surely be hungry today. Clemson's B. D. Cloaninger, director of fertilizer inspection and analysis, says:

South Carolina's 124,203 farmers use annually over 800,000 tons of fertilizer, at an estimated price of approximately 40 million dollars. Though this represents a large expenditure, numerous surveys reveal that for every $1 spent for commercial fertilizers, the farmer receives an average net return of $5. It has been aptly said that fertilizer is *comparable to interest*—things grow while one sleeps."

South Carolina was one of the states that started using fertilizer heavy from the time there was such a thing as "fertilizer." Even back in 1909 we used about as many tons as in 1957. But it was of a much lower grade and on more acres. Then it averaged only about 14 percent plant food. Now it averages a little above 23 percent. So it carries over 50 percent more power now!

Experiment and experience show we could profitably use more fertilizer than we now average. But, of course, fertilizer alone can't do it. It takes good husbandry all the way through. Then the fertilizer can pay off best.

Through long experience, I've noticed this, the farmer who uses the higher rates of fertilizer, in a good rotation program, is the one who lives in the big house and rides in the good car that's paid for.

J. M. Eleazer, Clemson Extension Information Specialist

THE EDITORS TALK

Of A Unique Idea

The Cooperative Grange League Federation Exchange in Ithaca, N. Y. has developed an interesting and, we believe, unique program for stimulating more soil testing among farmers in its area.

Cornell, Penn State, and Rutgers normally charge farmers $1.00 per sample for the basic complete soil test. Through its new program, GLF will pay this fee on receipt of proof that a sample has been tested according to George Serviss, GLF agronomist.

The local agent buys the boxes from the County Agent and is reimbursed when the Exchange has proof the samples have been tested.

To help reach as many farmers as possible, the Exchange arranged with FFA chapters last year to take samples on a fee basis. Half the cost of taking samples was paid by GLF, the other half by the local retail agency. Total cost for taking a sample was 40 cents.

This worked well—while providing a dual-result project: (1) It stimulated more farmers to have their soil tested; (2) It gave soil sampling experience to worthy FFA boys.

These young FFA farmers were trained in groups by County Agents and GLF Technical Field men on how to take samples. And most of them did a good job.

In New York, the interpretation of the soil is done by the County Agent. In Pennsylvania, it is done by College Extension specialists. And in New Jersey, the farmer can choose his sample tested by Rutgers or by the GLF Seabrook Farms Laboratory.

In all events, the Exchange asks no privileges —and gets none. It is strictly a program of stimulating more farmers to get into the profitable habit of having their soils tested.

PLANT FOOD ABSORBED BY CORN DURI

THE corn plant produces almost half of its total weight during one month of the growing season.

This is one of the interesting facts found in a research project carried on jointly by the Ohio Agricultural Experimental Station and the United States Department of Agriculture. In this experiment, they measured not only the amount of growth produced, but the amount of plant food absorbed during different periods.

The yield of corn in this experiment was approximately 100 bushels, and the total weight of dry matter (above ground) was 12,387 pounds. Weights of the various parts of the plant at maturity were as follows:

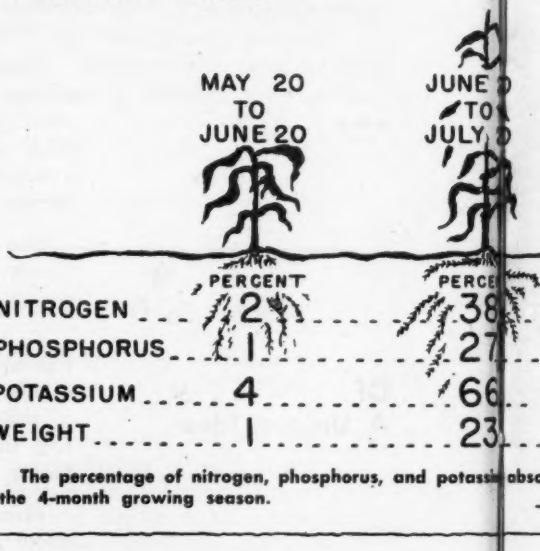
Leaves	*1,531 lbs.*
Stems	*3,462 lbs.*
Husks	*1,179 lbs.*
Cobs	*989 lbs.*
Grain	*5,723 lbs.*
Total	*12,884 lbs.*

The weight of the roots was not determined in this experiment. However, corn root studies made by Fahrenbacher and Snider at the Illinois Experiment Station indicated the root growth for a 100-bushel crop of corn would amount to about 5,350 pounds.

In the Ohio experiment, the 100-bushel crop of corn used 144 pounds of nitrogen, 30 pounds of phosphorus, and 98 pounds of potassium. *The amount of potassium in the corn plant actually reached 113 pounds. This high point was reached in August.* After about August 25, the amount gradually decreased because of loss of potassium from the plant.

The illustration shows the percentage of nitrogen, phosphorus, and potassium absorbed and the growth

A study showing that if high yields are to be produced, the soil must be able to supply large amounts of plant food to the corn crop during the period of rapid growth.

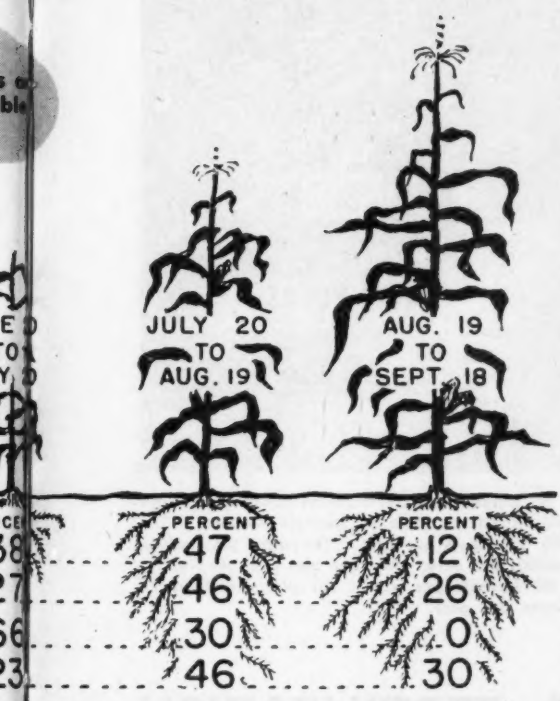


The percentage of nitrogen, phosphorus, and potassi abs the 4-month growing season.

produced each month during the four-month growing period.

During the first month after planting, the corn crop took up only 2 per cent of the total nitrogen absorbed during the entire growing season. Two per cent of the 144 pounds of total nitrogen would amount to only about three pounds. By July 1, the corn plant had taken up 15 pounds of nitrogen per acre. The corn crop therefore does not have to have a large amount of nitrogen available during the first month to six weeks after planting.

...URING DIFFERENT PERIODS OF GROWTH



...absorbed and the growth produced each month during
—Data from Ohio Agricultural Experiment Station

During the third month, however, —from July 20 to August 19—the plants took up about 67 pounds of nitrogen, or almost half of the total requirement. The greatest intake of nitrogen occurred during the last few days of July when the plants took up an average of four pounds per acre per day. This heavy requirement occurred about tasseling and silking time.

The plants absorbed only 1 per cent of phosphorus during the first month, but during the third month—from July 20 to August 19—they took up almost half of their total requirement for phosphorus.

It is interesting to note that corn plants take up potassium much earlier than they do nitrogen or phosphorus. In the Ohio tests, they took up 66 per cent of their potassium requirement during the second month. The maximum rate of potassium intake occurred during the second month when an average of 3.2 pounds per acre entered the plant. The potassium reached its maximum about three weeks after silking. After that time there was an actual loss, largely from the leaves and stems. Potassium may be partly washed from the leaves and stems back into the soil, or it may move back into the soil through the root system.

Results of this study show that, *if high yields are to be produced, the soil has to be able to supply large amounts of plant food to the corn crop during the period of rapid growth.* This has always been the goal of the Illinois Soil Program, and here is where the soil test comes in.

The soil tests will tell whether limestone, phosphate, and potash are needed and how much of each is needed per acre to supply the crop with plenty of plant food during the period of most rapid growth.

Testing to find out whether your soil can supply your corn crop with plenty of nitrogen when it needs it is neither so simple nor so satisfactory as testing for other elements. But previous cropping and soil treatment practices can be used as a guide in estimating nitrogen needs. ◄◄◄

—C. M. Linsley
Univ. of Illinois
Soil Fertility and Testing

Figure 1—When they started adding potash to balance the fertilization program on this Greenville, Kentucky plot, just 20 pounds of K_2O raised the yield 30 bushels per acre. The left plot, which received no potash, yielded only 5 bushels per acre. The right plot, which received 20 pounds K_2O per acre, yielded 35 bushels per acre. Another plot (not shown) receiving *80 pounds of K_2O per acre*, yielded *68 bushels per acre*. All plots received 75 pounds of nitrogen and 160 pounds of phosphate per acre.

BALANCED FERTILIZATION

FARMERS in Kentucky used more than 542,000 tons of fertilizer in 1957, containing nearly 190,000 tons of guaranteed plant nutrients.

A survey of the results obtained in the soil testing laboratories throughout the state shows that many of the fields tested needed relatively heavy applications of limestone, phosphate, and potash. A conservative estimate is that most farmers could *profitably double their present fertilizer usage with many benefiting from even greater increases.*

A farmer's profit depends largely on his production efficiency. Proper kind and amount of fertilizer, or balanced fertilization, is the first step in this direction.

Balanced fertilization may be defined as the application of that amount of each of the three major fertilizer elements—nitrogen, phosphorus, and

Dr. E. C. Doll heads all field work in soil fertility for the Department of Agronomy at the University of Kentucky. Montana native, he earned his B.S. and M.S. in Botany at Montana State, his Ph.D. at Wisconsin. He joined the Kentucky program in 1953.

✔ *In Kentucky, nitrogen, phosphorus, and potassium are frequently the limiting factors in plant growth. Also, boron is often needed for successful production of alfalfa and red clover seed.*

✔ *If* one *element is* deficient *in the soil, relatively heavy applications of the other fertilizer elements will be* ineffective.

✔ *Enough available phosphorus and potassium* should always *be present to cause maximum utilization of all the applied nitrogen.*

Figure 2—Here is typical potash-starved corn on the Greenville check plot, with stunted plants, short internodes, brown marginal-fired leaves, and early "root lodging"—all potash deficiency symptoms.

FIRST STEP TO EFFICIENT PRODUCTION

potassium—that will result in the most effective use of each element, considering both the immediate crop and succeeding crops.

Although the first step in building and maintaining a sound fertility program is the correction of soil acidity, limestone applications will not be considered here since they are more nearly a long-time investment rather than an annual or biennial operating expense.

By E. C. Doll [1]

Department of Agronomy

University of Kentucky

Mineral fertilizers are applied to soils to supplement those nutrient elements that are not already sufficiently available in the soil for optimum crop growth. *In Kentucky, nitrogen, phosphorus, and potassium are frequently the limiting factors in plant growth. Also boron is often needed for the production of alfalfa and red clover seed.*

No other elements have definitely

Table I.—The effects of various rates of nitrogen, phosphorus, and potassium on the yield of corn in Graves County, Kentucky, in 1955.

Treatment No.	Fertilizer Treatment (Lbs. N–P_2O_5–K_2O per acre)	Yield of Corn (Bushels per acre)
1	0– 0– 0	36.8
2	50– 50– 50	64.0
3	100–100–100	75.6
4	100– 0– 0	80.8

been found to be deficient, although some evidence indicates zinc may possibly be limiting corn production in certain areas. Obviously, a balanced fertilizer application would include only those elements needed for optimum production.

Experimental Results

One element lacking: The importance of balanced fertilization was strikingly illustrated in a corn experiment conducted in western Kentucky in 1955 (Table I). The difference in yield between treatments 3 and 4 is not significant.

In this particular experiment, nitrogen was the only element limiting production. Considering only the current crop (corn), the most efficient application would have been nitrogen alone. Previous results from soils in this area have shown, however, that phosphorus and potassium become limiting when this soil is intensively cropped for a few years. A sound soil fertility program would therefore need to include applications of these two elements.

Unbalanced fertilization decreases yields: If one element is deficient in the soil, relatively heavy applications of other fertilizer elements will be ineffective—as shown in Figure 1. Here the left plot was liberally fertilized with nitrogen and phosphorus. The right plot received potassium in addition. A two-year rotation of corn followed by wheat with a lespedeza-sweet clover cover crop has been followed for 11 years. Two series of plots enable each crop to be grown each year.

The average corn yields from 1952 to 1956 are given in Table II. The effect of improper fertilization is strikingly illustrated by the yields obtained for the past five years from the *plots to which no potash was applied.* When the experiment was started in 1946, higher yields were obtained from the plots that received the higher rate of nitrogen. Since no additional potash was applied, yields on the high-nitrogen plots have *rapidly decreased,* until now plots receiving the heavier rates of nitrogen produce the lowest yields.

An example of the potash-starved corn with short internodes and early "root lodging" is shown in Figure 2.

The yields of wheat, given in Table III, do not show so striking a response to potash as do the corn yields, although an excellent response was obtained for the first 20-pound increment of potash. Competition from the thicker stand and larger growth of legumes may have caused the lower yields of wheat obtained with the heavier rates of potash.

Legumes supplied most of the nitrogen: A lespedeza-sweet clover cover crop was seeded in the wheat, and the resulting growth plowed down for corn the following spring. The potash applications have a marked effect on the growth of the cover crop; *and at each level of potash, the legumes are apparently fixing nearly enough nitro-*

Table II.—The effects of various rates and combinations of nitrogen and potassium on the average yield of corn from 1952 to 1956 at Greenville, Kentucky. Phosphorus was applied to all plots at the rate of 160 pounds of P_2O_5 per acre per year. A two-year rotation of corn and wheat with lespedeza-sweet clover cover crop is followed.

Pounds Nitrogen (N) per acre		Yield of Corn (Bushels per Acre)				
		Pounds Potash (K_2O) per acre*				
Corn	Wheat	0	20	40	80	160
0	0	30.6	34.6	42.7	52.6	52.3
25	15	20.9	31.1	46.2	56.1	55.4
50	30	18.0	36.7	44.7	55.8	56.4
75	45	12.4	36.0	47.7	53.1	53.7

* Potassium applied at the same rate for wheat.

gen for maximum yields of corn.

The yields given are the average of five years' data. Examining the individual yields for each year, we find additional nitrogen was required for yields in excess of 70 bushels of corn per acre.

With wheat, an excellent response was obtained for the first 15 pounds of nitrogen, and a smaller but still economical response for the second 15-pound increment of nitrogen. Although an excellent legume cover is plowed down for the corn, additional nitrogen is required for the succeeding wheat crop.

Steps Leading to Balanced Fertilization

The above data clearly show the need for properly fertilizing the particular soil according to the requirements of the crops to be grown.

Past experience in Kentucky has shown that sound fertilizer recommendations can be made *if reliable soil test results and a complete cropping and fertilizing history are available.* Additional research is being conducted to improve soil testing procedures and interpretations and to give further information concerning fertilizer responses on various soils throughout the state.

Lime: Most of the upland soils in Kentucky are acid and will benefit from limestone applications. The soil should be maintained at approximately pH 6.5 for most farm crops. Since the lime requirements of alfalfa are relatively high, the soil should be limed to pH 6.7 to 7.0 for best alfalfa production. For tobacco, the best quality is usually obtained when the soil is maintained at pH 5.8.

The test for acidity is the simplest,

Table III.—Effects of various rates and combinations of nitrogen and potassium on the average yield of wheat from 1952 to 1955 at Greenville, Kentucky. Phosphorus was applied to all plots at the rate of 160 pounds of P_2O_5 per acre each year. A two-year rotation of corn and wheat with a lespedeza-sweet clover cover crop is followed.

Pounds Nitrogen (N) per acre		Yield of Wheat (Bushels per Acre)				
		Pounds Potash (K_2O) per acre*				
Corn	Wheat	0	20	40	80	160
0	0	16.7	22.3	24.1	19.3	18.5
25	15	26.1	31.7	31.2	30.3	26.5
50	30	26.0	34.3	36.4	32.5	28.0
75	45	19.9	35.4	36.4	33.6	31.9

* Potash is applied at the same rate for corn.

most accurate of the soil tests made in Kentucky and should always be used as the basis for limestone applications. Once the soil has been adequately limed, another test for soil acidity would be advisable *after four or five years of intensive cropping.*

Phosphorus: Long-time fertility experiments conducted in Kentucky have shown the desirability of building up and maintaining a high level of available phosphorus in the soil. Nearly all Kentucky soils, excepting the high-phosphate area in the Central Bluegrass region and certain overflow soils along the Mississippi and Ohio Rivers, respond markedly to phosphate applications. Since it is relatively easy to maintain a high level of available phosphorus in the soil, *phosphorus should never become the limiting factor in crop production.*

Potassium: Under intensive cropping, most of Kentucky's upland soils will respond to potassium applications. It is generally known that hay crops will take up more potassium than is necessary for maximum yields. For these reasons, it appears most economical to apply only enough potash to supply the needs of the immediate crop. Even under these conditions, however, the level of available potassium will tend to increase, and periodic soil tests are needed to determine the level of soil potassium.

Nitrogen: Since no soil tests for available nitrogen are made in Kentucky, nitrogen needs are estimated from the past fertilizing and cropping history and the crop to be grown. When a systematic rotation is followed, including one or more years of grass-legume soil, a large portion of the nitrogen needed by the grain crops can be supplied by the legumes. Any available nitrogen not used by the immediate crop may be subject to loss by leaching unless a vigorous winter cover crop is grown, so only enough nitrogen for the immediate crop should be applied. Since nitrogen is the most expensive of the three major fertilizer elements (nitrogen, phosphorus, and potassium) and since it has the least residual effect, *enough available phosphorus and potassium should always be present to allow for maximum utilization of all the applied nitrogen.*

Seeding Operations

After a farmer has limed and fertilized his land as needed, he should plant adequate quantities of good seed in a well-prepared seedbed if he is to realize the greatest return on his investment. High-quality seed is necessary for a good stand of healthy, vigorous plants. Certified seed, if available, is always recommended. A well-prepared seedbed causes good contact between the seed and the soil, is firm enough for good moisture conditions, yet loose enough for proper aeration. Good stands are essential for good use *of adequate fertilization.*

Summary

The fertilizer recommendations made by the Kentucky Agricultural Experiment Station were developed by the procedures described above and are based upon many years of field, greenhouse, and laboratory studies. The following steps will lead to more efficient production:

1. Sample and test the soil.
2. Apply lime and fertilizer according to recommendations made on the basis of soil tests and past cropping and fertilizing history.
3. Plant adequate quantities of good seed in a well-prepared seedbed.
4. Control pests. ◄◄◄

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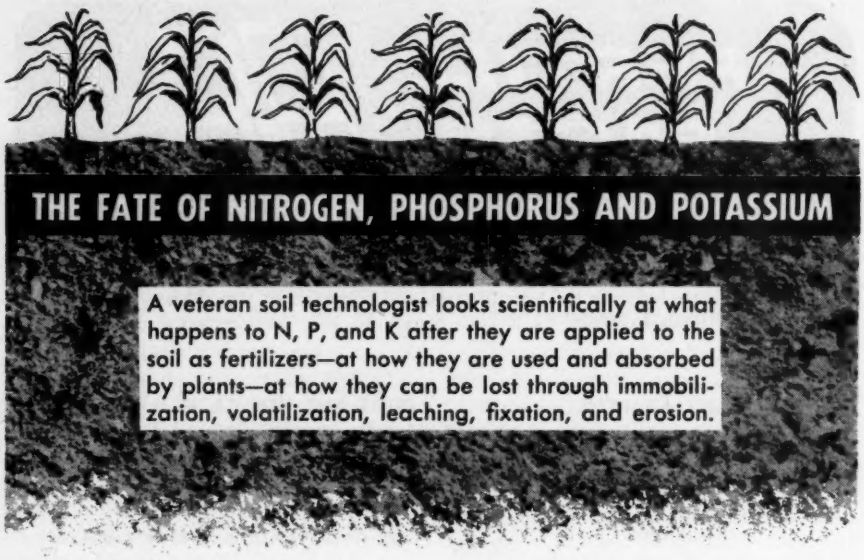

THE FATE OF NITROGEN, PHOSPHORUS AND POTASSIUM

A veteran soil technologist looks scientifically at what happens to N, P, and K after they are applied to the soil as fertilizers—at how they are used and absorbed by plants—at how they can be lost through immobilization, volatilization, leaching, fixation, and erosion.

NITROGEN, phosphorus, and potassium are the three nutrient elements most commonly deficient in soils for optimum crop production.

The present and future capabilities of farmers to produce the foods and fibers required by civilization stems, in very large part, from the judicious use of these elements, along with lime and such other plant nutrient elements as may be needed in specific cases.

What happens to nitrogen, phosphorus, and potassium after they have been applied to the soil as fertilizers is very important to our agricultural production and economy. Let us consider their fate in broad outline.

Nitrogen

Nitrogen may be added to the soil in nitrate, ammonium, or organic forms. With the exception of certain insoluble organic forms, nitrogen fertilizers are completely soluble and immediately enter the soil solution when applied to the soil.

One or more of the following fates may befall nitrogen shortly after it is applied as a fertilizer:

(1) It may be absorbed and utilized by plants.

(2) It may be immobilized as a result of microbial activity.

(3) If in forms other than nitrate, it may be oxidized to the nitrate form.

(4) If present as nitrate, it may be leached from the root zone by excess water, or reduced and lost to the atmosphere as nitric oxide, nitrous oxide, or nitrogen gas.

(5) If in the ammonium form, it may be adsorbed by the soil particles in exchangeable form, after which a portion of it may be "fixed" by the clay minerals in such a way that it is not immediately available to plants; under some conditions, it may be volatilized and lost to the atmosphere as ammonia.

(6) It may be lost by erosion of the top soil.

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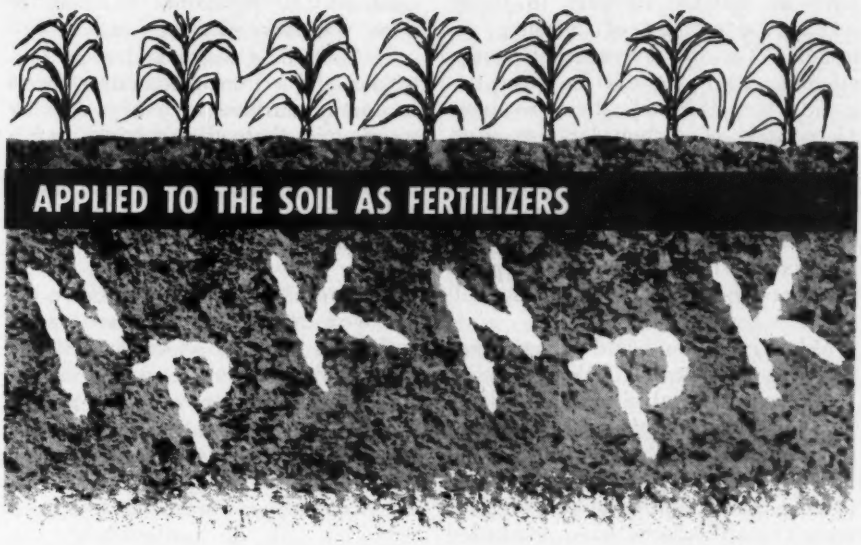

In many experiments, attempts have been made to account completely for the nitrogen applied as fertilizer. It has seldom been possible to prepare a balance sheet that satisfactorily accounts for the fate of all the nitrogen applied.

Use by plants

It is a fairly simple matter to analyze harvested crops for total nitrogen and calculate the nitrogen removed as a percentage of that applied as fertilizer. This has been done in hundreds of experiments. The recovery of added nitrogen, calculated in this way, varies greatly, depending on soil and climatic conditions and on how, when, at what rate, in what form, and to what crop applied.

Commonly, 25 to 75 percent of fertilizer nitrogen is recovered in the harvest of the crops to which it is applied. These values do not account for nitrogen present in the roots left in the soil nor for other forms of residual nitrogen which may be available to later crops.

Immobilization

Immobilization is a term applied to the processes by which soil microbes lock up nitrogen in the soil in complex organic forms that make it temporarily unavailable to crops. Most of this nitrogen is eventually made available by the reverse process, called mineralization. Nevertheless, from a short-term standpoint, immobilization may have very marked effects upon the availability of nitrogen to crops.

The extent of immobilization of added nitrogen depends on the amount of soil organic matter and the carbon-nitrogen ratio in the soil, as well as the soil moisture and temperature conditions.

When easily decomposible organic matter is worked into the soil, it serves as food for the microbe population. If moisture and temperature conditions are favorable, the numbers of

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microbes quickly increase to limits set by the amount of available nitrogen. On the average, after the microbes have worked over the organic materials in soils, there are about 11 pounds of carbon left for each pound of nitrogen, giving a carbon-nitrogen ratio of about 11 to 1.

Many plant residues contain 20 to 80 times as much carbon as nitrogen. In decomposing or rotting these plant residues, the microbes may use all the nitrogen available.

When crop plants and soil microbes compete for nitrogen, the microbes "eat at the first table" and the plants get only what is left. The nitrogen used by the microbes is incorporated into their tissues and is not available to crop plants until the processes of organic matter decay have proceeded to the point where the carbon-nitrogen ratio has been lowered to about 11 to 1.

This may take only a few days after organic matter and nitrogen are added to the soil or it may take several weeks, depending on the soil moisture and temperature conditions as well as the amount of nitrogen and the amount and kind of organic matter.

When the organic matter has been decomposed to such an extent that the carbon-nitrogen ratio in the soil is about 11 to 1, the processes of mineralization begin to make previously immobilized nitrogen available to crops, first as ammonium and then as nitrate.

Leaching losses

Because *nitrate nitrogen* is an anion and both it and the soil particles have negative electrical charges, they are not attracted to each other; therefore, nitrate is not adsorbed and held by the clay particles to any significant extent.

Ammonium nitrogen, on the other hand, is positively charged and is attracted and held by the negatively charged soil exchange complex in the same way as potassium, calcium, or other positively charged cations.

If the soil is warm and moist, nitrogen applied in ammonium forms is usually nitrified in a few days or weeks and thereafter behaves as nitrate. If the soil is too cold for nitrification to occur rapidly, ammonium will remain largely as ammonium until the soil warms up to about 40°F or higher.

Nitrate nitrogen moves freely in the soil with the soil water. Anytime the soil takes in more water than it can hold in the root zone, nitrate may be lost in the drainage water.

Ammonium nitrogen is ordinarily not lost by leaching in any considerable amounts except when relatively large applications are made to coarse-textured soils of low exchange capacity and low water holding capacity. Such soils may have insufficient exchange capacity to adsorb and retain the amount of ammonium applied as fertilizer, causing it to pass through the soil with the drainage water and be lost from the root zone.

Loss of nitrogen from soils by leaching of nitrate in drainage water is affected by several factors and may vary greatly in different situations. Any amount of water moving downward from the soil surface tends to leach the nitrate nitrogen *out of the topsoil. But unless there is drainage from the root zone the nitrate will be left where plants can get it.*

In the semi-arid summer-fallow wheat areas of the west, water from winter rain and snow often carries nitrate out of the surface soil and deep into the root zone where it cannot be obtained by plants until their roots have extended to it.

The greater the moisture holding capacity of the soil and the deeper the root zone the less likelihood of nitrate loss by leaching.

The presence of actively growing plants with extensive root systems reduces leaching losses.

Nitrogen immobilized by microbial

processes is not subject to leaching until it has been mineralized.

Our best quantitative information on nitrogen losses from soil by leaching comes from lysimeter experiments. A lysimeter may be termed a giant buried pot in which soil is maintained under near-natural conditions. It usually holds several hundred or a few thousands pounds of soil. The bottom of the lysimeter is provided with a drain and a collector for any water coming through the soil. Periodically the drainage water is analyzed chemically for the amount of nutrients it contains.

In a 15-year lysimeter experiment at Cornell University, leaching losses averaged 23 percent of 143 pounds N per acre applied as sodium nitrate or ammonium sulfate to a sandy loam soil that grew two vegetable crops and a winter cover crop each year.

In an 8-year experiment, the leaching losses were only about 2 percent of the nitrate nitrogen applied (93 to 213 pounds nitrogen per acre) to a timothy sod on a silty clay loam soil.

In a 10-year experiment, in which 200 pounds of nitrogen per acre were applied annually to tobacco on a sandy loam soil in Connecticut, from 40 to 55 percent was lost by leaching.

When 100 to 200 pounds of nitrogen per acre were applied to sudangrass on a loam soil, at Riverside, California, 31 to 36 percent was lost annually in the leachate. When a winter cover crop followed the sudangrass, the loss was reduced to about 15 percent.

Other data are available to show that leaching losses may vary from almost nothing to very significant amounts, depending on conditions.

Volatilization

It is almost never possible to account fully for all the nitrogen applied to soils as fertilizer. After measuring nitrogen removed in crops, that remaining in the soil and that lost by leaching, there is often 15 per cent or more of the original application that cannot be accounted for.

In the lysimeter experiments just mentioned, 3 to 24 percent of the nitrogen added to the soil could not be accounted for in crop, soil, or drainage water. The average was about 15 per cent. Microbiologists suspect most of this nitrogen is lost by volatilization.

Under suitable conditions, ammonium nitrogen may be rapidly lost by volatilization. Such losses may total 25 percent or more of the ammonium nitrogen added to the soil or formed by decomposition of organic materials.

Very little, if any, ammonium is volatilized from moderately or strongly acid soils. Barely detectable volatilization may occur at pH 6 to 7, but losses increase greatly at pH values in the alkaline range. Even if the soil is acid, volatilization losses may be high if organic materials high in nitrogen decompose on or near the surface, because of the locally high pH produced by the ammonium formed.

Losses from wet soils are usually small. But if an alkaline soil containing much ammonium is dried, losses may be very high. *Volatilization increases with soil temperature.* Losses from coarse-textured soils of low exchange capacity are greater than those from finer-textured soils.

Much more serious volatilization losses of nitrogen from acid soils of the humid regions are thought to occur as a result of formation of nitric oxide (NO), nitrous oxide (N_2O) or nitrogen (N_2) gases, largely the latter. It is generally assumed that the denitrification processes resulting from microbial action are responsible for most of the losses of fertilizer nitrogen that cannot be accounted for in crop, soil, or drainage water, and for the failure of nitrogen balance sheets to balance.

Laboratory studies have shown these gases may be produced from

nitrate under reducing conditions. It is practically impossible to measure their evolution directly except under laboratory conditions.

Denitrification losses can occur wherever there are relatively large amounts of nitrate and a deficiency of oxygen for any reason, such as water-logging, soil crusting, or the presence of large amounts of easily decomposable organic matter. Until fairly recently, we thought microbial denitrification occurred only under completely anaerobic conditions, but we now know small amounts of denitrification can take place under aerobic conditions.

Ammonium fixation

In recent years, numerous laboratory investigations have shown some soils are able to fix fairly large amounts of ammonium nitrogen in non-exchangeable form, usually when wetted and dried but in some cases without drying. This phenomenon will likely receive more attention as the use of ammonium fertilizers increases.

Apparently, ammonium fixation occurs by the same mechanism as potassium fixation. The ammonium of potassium ion migrates between the expanded lattice sheets of clay particles. As the soil loses water by drying, the lattice shrinks and the presence of the ion offers such attraction that the re-expansion of the lattice does not readily occur, preventing outward migration of the ion.

Usually rather small in magnitude, astonishingly large amounts of ammonium fixation by soils in the laboratory have been reported in some cases. A California soil was found to fix 1,120 pounds of nitrogen per 2 million pounds. From 14 to 30 percent of the fixed ammonium was nitrified during a 2-week Neubauer test.

A Webster soil in Iowa was found to fix 280 pounds of ammonium nitrogen per 2 million pounds soil when moist and six times this amount when dried at 100° C. Usually less than 10 percent of the fixed ammonium was nitrified in 16 weeks.

The practical importance of ammonium fixation under field conditions remains to be determined. It is not too important in soils of the humid areas at the present time. It may be more important in western areas where much of the nitrogen used is applied as anhydrous or aqua ammonia.

Two facts seem to indicate ammonium fixation may not have great practical importance under field conditions: (1) In field experiments, ammonium forms of nitrogen usually give as good yield responses as other forms. It seems when ammonium is fixed under field conditions, either it becomes available eventually to plants or losses of other kinds of nitrogen by other means compare in amount. (2) Although soils have contained some ammonium since shortly after they first began to grow plants, they still have ability to fix ammonium. If ammonium is permanently fixed, the fixing capacities of most soils should have been satisfied long ago.

Phosphorus

Most phosphorus used in fertilizers is applied as superphosphate, either ordinary or concentrated. Unlike nitrogen, phosphorus is not lost by volatilization and losses by leaching are usually inconsequential. It may be lost by erosion if the topsoil is carried away or it may be carried off in surface water after the first heavy rain if surface-applied.

When phosphate is applied to the soil, it may be absorbed by plants or it may undergo fixation.

Phosphorus fixation is a broad term, embracing all the processes by which phosphorus added to soil becomes insoluble. *Usually not more than 5 to 30 percent of the phosphorus added to soils is utilized by the crop to which it is applied.* The 70 to 95 percent not used by the crop is fixed in the soil.

Phosphorus accumulates wherever application rates exceed the amounts removed by crops. A survey of the phosphorus status in potato soils along the Atlantic seaboard, from Maine to Florida, a few years ago showed the total phosphorus content of some of the soils had increased five-fold through repeated fertilization with phosphate.

Contrary to long-time belief, modern evidence has shown *phosphate fixation reactions are not irreversible.* The term *fixation* is an exaggeration. The present view is that, in acid or neutral soil, some of the fixed phosphate is converted quickly to an adsorbed form that can be utilized by most plants. In time, this initial form is gradually converted to a less soluble, less available form. The time required for conversion depends on the phosphorus status of the soil and the amount of phosphate added but usually takes several months.

At various times fixation has been attributed *to assimilation by microorganisms,* to *chemical precipitation by soluble ions in the soil solution,* and to *sorption of phosphate on the soil complex by physicochemical means.*

We now generally agree fixation by microbes is relatively unimportant—and that *sorption and precipitation cause most of the fixation we observed. There is still much uncertainty over what reactions are involved and what compounds are formed.*

Much study has been made of the role of iron and aluminum compounds. Formation of such compounds, undoubtedly, accounts for some phosphate fixation in acid soils. During the past five to ten years, several investigations have concluded that phosphate fixation by clays of acid soils occurs largely, or at least partly, through reactions with the aluminum of clay minerals, through a mechanism essentially like chemical precipitation in solution.

Anion exchange, or the exchange between hydroxyl ions in the structural surface of the clay minerals and phosphate ions in soil solution is another mechanism by which phosphorus may be fixed, although few workers now consider this important.

Today's dominant theory says fixation of phosphorus in acid soils is due primarily to the formation of iron and aluminum compounds by either adsorption or precipitation.

Several investigators have prepared some of the compounds of iron and aluminum with phosphate, thought to be formed during fixation. Plants are able to obtain considerable phosphate from precipitated iron and aluminum phosphates. Truog of Wisconsin found aluminum phosphate gave 75 to 100 per cent as good yields of several plants as superphosphate. Others have also found plants can obtain phosphorus from iron and aluminum phosphates.

In neutral or alkaline soils of semiarid and arid regions, the formation of iron and aluminum phosphates is of minor importance. Phosphorus fixation in these soils is generally considered due to reactions involving calcium. When soluble phosphorus fertilizers are added to calcareous soils, the phosphorus is adsorbed on the surface of calcium carbonate particles or other surfaces containing calcium, or it is precipitated, probably at first as dicalcium phosphate. In these forms, the phosphorus is available to plants. The formation of hydroxyapatite or other apatitic minerals, it appears, is the ultimate fate of most of the phosphorus applied to highly calcareous soils and not taken up from the soil solution by plants. Some plant species are more effective than others in obtaining phosphorus from apatites.

The reactions by which phosphorus is fixed in soils apparently are not wholly irreversible. So-called fixed phosphate is usually reasonably available to plants for several months. With the passage of time, it may become less available, particularly if

scattered throughout the plow layer by tillage operations.

Results of numerous experiments to measure the availability of phosphorus in neutral and alkaline soils of the semi-arid and arid regions of the west show that considerable amounts of applied phosphorus may *remain available for several years.*

Liming is one of the most important factors in increasing the availability of fixed phosphorus in acid soils. Phosphorus availability is at its maximum in the range of *pH from 6 to 7* and is increased if acid soils are limed or alkaline soils are acidified to bring the reaction into the range.

Another way to reduce phosphorus fixation and help make fixed phosphorus more available is to work manure and crop residues into the soil. Part of their effect may come from formation of organic chelates of iron and aluminum. The presence of biologically active organic matter possibly exerts a protective effect on the soil colloids.

However, neither liming nor additions of organic matter nor any other practice has been found to completely prevent fixation or make available all the phosphorus that has been fixed in soils. Much research yet remains to be done on the problems of phosphorus fixation.

Potassium

Potassium is present in soils in several forms, ranging in availability from that in the soil solution to that present as an essential constituent of the primary minerals from which it is released only when the crystal structure is destroyed.

A small amount is present in the soil solution. Much more is present in the exchangeable form. A still much greater amount is present as a *difficultly available or unavailable constituent of the soil minerals.*

The several forms are in somewhat of an equilibrium, and a change in the amount of one is reflected in changes in amounts of one or more of the others. Often the sum of the amounts present in the soil solution and in exchangeable forms adsorbed on the soil particles is less than the amount absorbed by plants during one season.

Regardless of the form in which it is applied to soils—whether in fertilizer salts, manure, or crop residues—potassium soon enters the soil solution where one or several of the following may occur:

(1) *It may be absorbed by plants.*

(2) *It may exchange with other cations on the surface of the clay particles and become adsorbed but remain available to plants, since exchange reactions can readily return it to the soil solution.*

(3) *It may be adsorbed by the clay particles in forms at first available and then, by fixation reactions, change over gradually to forms difficultly available or unavailable to plants.*

(4) *It may be lost from the root zone by leaching.*

(5) *It may be lost by erosion if the topsoil is carried away.*

Absorption by plants

For soils on which potassium application causes crop yield increases, when the potassium removed in crops is calculated *as a percentage of that applied,* recovery values are frequently in the range from 50 to 100 percent and *sometimes exceed 100 percent,* especially where small applications are made to crops that take up large amounts of this element.

In this respect, potassium's behavior is in sharp contrast to that of nitrogen or phosphorus, particularly the latter.

Fixation

Under average circumstances, the major portion of potassium applied as fertilizer is retained in the soil in exchangeable forms available to plants. A smaller portion undergoes fixation.

Under certain conditions, many workers have found, potassium may

become fixed in soils in forms unavailable or difficultly available to plants. About 60 years ago, Rothamsted workers found that of over 4,000 pounds of potash per acre applied to the Hoos field over a 38-year period *only about half* could be accounted for in the harvested crops and in the citric acid soluble potassium present in the soil. Data from a nearby field indicated that leaching losses averaged 10 pounds per acre per year, therefore it was assumed that most of the potassium unaccounted for had changed over to difficultly soluble form.

Probably the earliest observations on potassium fixation in America were made on the famous Jordan plots in Pennsylvania about 40 years ago. One plot had received a total of 1,800 pounds of potash per acre in 36 years. About a fourth of this amount had been removed in crops, about half was present in exchangeable form, and the remainder had apparently been fixed in nonexchangeable forms.

Numerous investigations in recent years have left no doubt of the ability of many soils that have the 2:1 type of layer lattice clay minerals to fix potassium in nonexchangeable or difficultly available forms when they are alternately wetted and dried. A few soils have been found to fix potassium in the moist state. Soil minerals of the 1:1 layer lattice type have little or no capacity for fixation.

In minerals of the expanding lattice type, potassium migrates into the particles between the silica layers. When the minerals are dehydrated by drying, the lattice layers shrink together and the potassium is locked up in such a way that it cannot readily migrate back to the surface. The potassium has such attraction for the lattice layers of the minerals that their re-expansion and hydration is retarded.

Although fixed potassium, in most instances, is not permanently lost and gradually becomes available as the minerals rehydrate and expand, fixation may be very important at certain times of the year, especially on soils low in exchangeable potassium. In numerous experiments, the levels of exchangeable potassium in such soils decrease during the summer and then increase in the fall and winter to approximately the levels present in the spring. This indicates two things —that potassium fixation reaction is reversible or at least partly reversible and that crops can remove relatively large quantities of potassium from some soils with little decrease in the exchangeable form.

Nevertheless, fixation can reduce the availability of applied potassium for a time.

Leaching

Numerous studies have been conducted on the amount of potassium lost from soils by leaching. Under some conditions, considerable loss occurs. About 70 pounds of potash per acre were lost annually from the silt loam and silty clay loam soils in the Cornell lysimeter experiments already mentioned. This loss may be higher than that of ordinary circumstances from field soils, for surface runoff was prevented and about 60 percent of the precipitation appeared as drainage.

At Rothamsted, from 3 to 11 pounds of potash were lost each year in the approximately 10 inches of drainage water from plots manured or treated annually with 300 pounds of potash per acre.

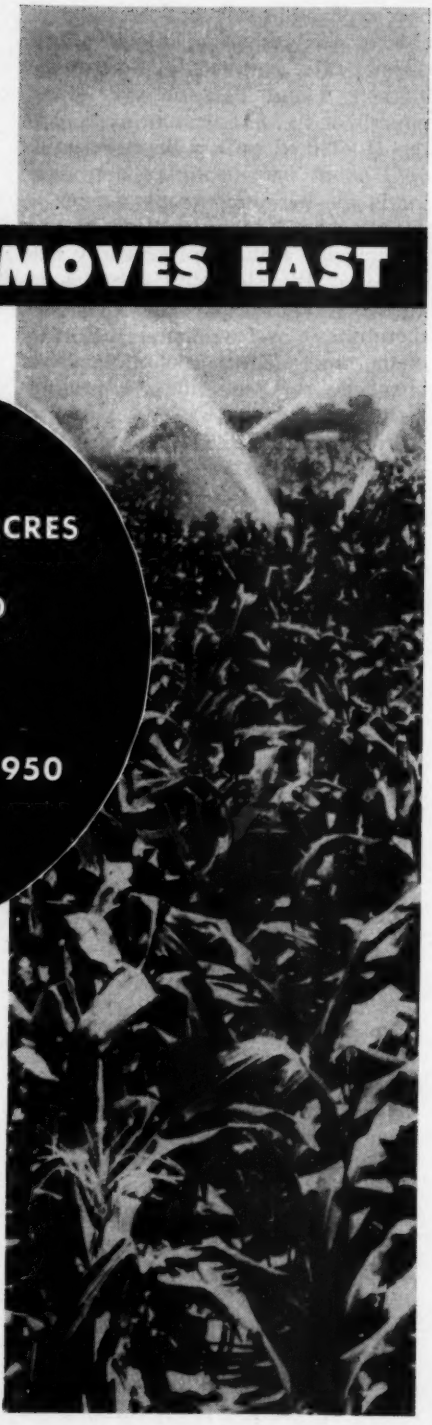
A leaching loss of about 10 pounds per acre annually was observed in Scotland.

In Texas, only very small amounts were lost in leachings from lysimeters, even at high rates of potash application. After reviewing the available literature, Truog and Jones concluded that under most farming conditions 10 to 15 pounds of potash per acre were lost from leaching in soils of the humid zones.

When the land is in perennial crops,

(Continued on page 43)

IRRIGATION MOVES EAST



WHERE IRRIGATED ACRES HAVE INCREASED FROM 500% TO 1000% SINCE 1950

FROM Maine to Florida more and more farmers are irrigating their crops to increase yields. Irrigation is moving East.

In the dry, subhumid Western States, irrigation has been practiced for generations, but in the East, irrigation of many crops is new and growing.

Before irrigation came East, a frequent question of one farmer to another was, "Do you think it's going to rain?"

And a frequent answer was, "If it doesn't, there is going to be a long dry spell."

Now, what were your questions? Oh, yes! *"Why is irrigation becoming so popular in the East? Don't most Eastern States receive quite a lot of rain every year? They say a good irrigation farmer never looks up for rain clouds, but do eastern farmers really irrigate in a drizzling rain? What are the facts?"*

By SCOTT A. MILLER, USDA AGRICULTURAL RESEARCH SERVICE

To begin with, Eastern States receive an average yearly rainfall of 40 or more inches of which 20 to 30 inches occur during the summer growing season. One year out of four, however, the average rainfall for the summer growing season is *6 to 12 inches.*

Not only does the weather vary considerably from year to year, but season to season and day to day. Highest recorded rates for eastern rainfall are 6 to 12 inches per day for just one day.

Length of drought periods vary, too. For example, during the past 82 years in South Carolina at least 238 *droughts* of two weeks duration or longer have occurred. In 75 out of these 82 years, droughts exceeded 30 days. Two years out of 5 had a total of 60 or more drought days during the growing season.

In Massachusetts and New York, one or more droughts occur sometime during the growing season about two years out of three.

To sum up, rainfall in the humid East is sporadic and many farmers are supplementing natural rainfall to crops with irrigation during drought periods.

How has supplemental irrigation worked out? Fifty-three Pennsylvania farmers were interviewed. About 80 per cent of the farmers said that crop yields were increased up to 60 per cent as a result of irrigation and that they definitely would continue the practice. The rest felt that irrigation was so new to them that they did not have enough experience to give an opinion of its value.

A dairy farmer in Vermont paid for his irrigation system in just two years through increased milk production. Another dairy farmer with irrigation netted about $300 per acre compared to about $90 per acre net profit for the farmer without irrigation.

A New Hampshire farmer raised 704 bushels of potatoes per acre under irrigation. Mr. Henderson from South Carolina grew *110 bushels* of corn per acre by irrigation while in a nearby field non-irrigated corn produced *only 8 bushels* per acre.

In general, supplemental irrigation appears to be a profitable practice for more and more farmers in the humid East.

Irrigation has many uses. Many farmers prefer to irrigate high-value crops, such as potatoes, cotton, corn, and tobacco; or truck crops, such as cabbage, tomatoes, sweetcorn, peas, beans, cucumbers, squash, melons, carrots, and berries; or orchard crops, such as peaches and apples.

Dairy farmers often find irrigation of productive alfalfa, ladino, and bromegrass for hay and pasture is profitable.

Dr. Scott A. Miller, soil scientist with USDA Agricultural Research Service at Mesa, Arizona, evaluates physical problems of soils in relation to crop production and water conservation. He was formerly professor of soil physics at the University of New Hampshire.

Rural and suburban non-farmers are irrigating lawns, flowers, fruits, vegetables, airports, cemeteries, parks, highway embankments, and golf courses on an unprecedented scale.

Of all the many irrigation methods, perhaps the most popular in the East is the sprinkler irrigation.

The introduction and use of lightweight, portable aluminum irrigation tubing and quick couplers about a decade ago has since spread like wildfire and in no small way explains why irrigation is moving East.

Since 1950, the number of irrigated acres in eastern coastal states has increased from 500 to 1,000 per cent.

Soils best suited for irrigation are generally the light-to-medium textures, such as fine sandy loam. A permeable soil with good drainage is essential.

Many different eastern soils meet these requirements and produce very high yields *when fertilized heavily and irrigated to provide optimum amounts of water.* Many crops require about one-acre-inch, or over 26,000 gallons, of water each week during the growing season.

Some farmers irrigate according to a weekly schedule. Others prefer to use inexpensive soil moisture meters and apply water as needed by the crop.

The cost to develop a suitable irrigation system varies from $1,500 to $15,000. The average cost in 1956 was approximately $4,000.

Technicians of the Soil Conservation Service help a farmer determine the design of irrigation equipment needed for a particular farm. The equipment should be large enough to cover all the acres at a suitable rate and small enough to work near peak capacity.

Two of the most common problems encountered are the time-consuming jobs of moving sprinkler irrigation pipes and inadequate supplies of water. The amount of experience a farmer has had with irrigation affects the labor requirements.

On an average, about four man-hours per acre are required for each irrigation. The more the equipment is used and the more experienced the farmer, the less time required per acre per application.

The problem of inadequate water supplies is being met, in many cases, by farm ponds or deep wells where water from nearby streams or shallow wells is unavailable.

Of course, irrigation is not the whole answer and is not a substitute for good farm management.

Crop rotation, application of lime and fertilizer, insect and weed control, and many other good farm management practices are essential for a successful irrigation system.

An irrigation system—perhaps more than any other piece of farm equipment—is really a kind of insurance. In Eastern States, irrigation may be needed only two years out of every three, but it "pays off" during drought years when natural rainfall is insufficient for normal plant growth.

To decide whether irrigation is likely to be profitable on his farm, a farmer needs to balance the value of additional yields when irrigation is necessary against the cost of maintaining and operating the irrigation system.

One eastern farmer puts it this way, "Well, I'll tell you. I'm what folks call a successful failure. I was a dryland marginal farmer for 20 years. I had my ups and downs, and with the pesky weather it seemed like more downs than ups.

"Now, after trying irrigation for just five years, I've paid off most of the mortgage. I'll admit it costs more to operate an irrigation farm and it takes more work and planning, *but it's worth it.*

"Summer droughts don't bother any more, and I enjoy helping plants grow more than watching them wilt in the sun. Yep, I'm a successful failure all right and a good one at that, thanks to irrigation." ◄◄◄

FATE OF NPK—*Continued from page 39*

the leaching losses are still less. There is danger of serious loss only when heavy applications of potash are made to soils of low exchange capacity, and then only when excessive amounts of water drain through the soil.

Erosion Losses

Because of similar factors involved, erosion losses of nitrogen, phosphorus, and potassium are considered together.

Unfortunately, just those fractions of the soil most active in *adsorbing and retaining nutrients applied in fertilizer* are most likely to be carried away by either water or wind erosion.

Fertilizers are usually applied to the topsoil, frequently on the surface and seldom more than a few inches deep. The greatest concentration of organic matter, with high exchange capacity and some biologically fixed nutrients, is in the topsoil.

The finer soil particles, clay and fine silt, are the first to go into suspension in flowing water or to be picked up by wind. Any exchangeable or fixed ammonium or potassium or fixed phosphorus associated with these soil fractions will, of course, be lost if they are removed from the site.

The amount of nutrients supplied in fertilizers that may be lost by erosion depends on both the kind and amount of erosion that occurs. Sheet or rill erosion by water or surface erosion by wind is likely to carry away more applied nutrients than gully erosion, when the same amount of soil is lost in each case. This is because of the greater proportion of surface soil removed.

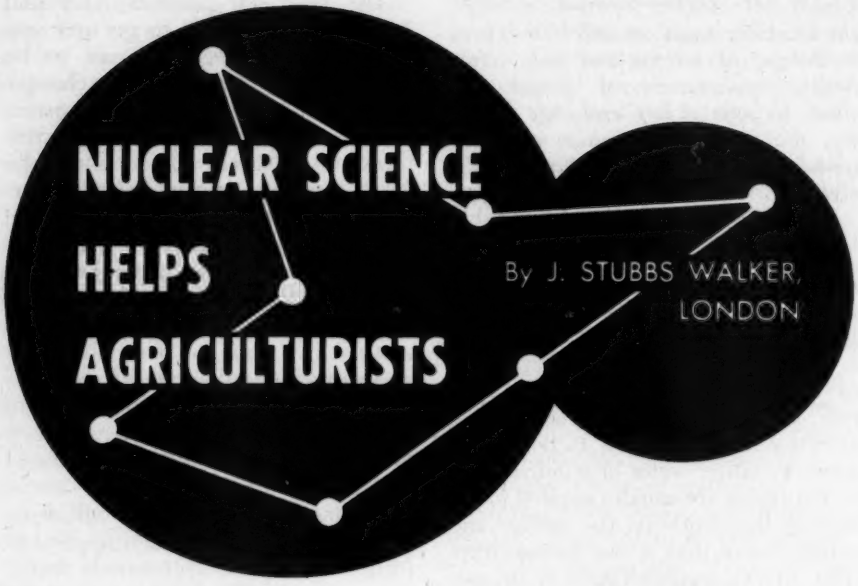
Significant amounts of nitrogen, phosphorus, and potassium applied in fertilizers may be irretrievably lost if erosion losses of soil are severe.◄◄◄

* Professor of Soil Technology, Department of Agronomy, The Pennsylvania State University.

FARM POND MANAGEMENT TIPS

1. Weeds around fringe of pond are not bad. *Excessive* vegetation can be detrimental, though. If pond bottom is choked with weeds, correct by fertilizing (inorganic fertilizer) enough to shade out the growth. Or, eliminate shallow, marshy edges.
2. Harvest as many fish, especially bluegills, as possible. It's virtually impossible to "fish out" a pond with normal sport fishing methods. Heavy fishing can actually help fish production!
3. Begin fishing in any pond after bass have spawned the first time.
4. Constantly roily water does not permit the best fish production and growth. Watershed should be sodded, never over-grazed.
5. Local SCS personnel are usually best informed on farm pond management. Some fish and game departments have pond experts on their staffs, too. Contact them when problems develop.

—*From Ford Farming*



NATURE moves very slowly. Natural mutations go on imperceptibly.

But with the new atomic tools of science in recent years, man has been able to speed up nature's changes, select those that are for the good and, in only a few seasons, produce changes in plants and crops that might have taken nature half-a-dozen centuries.

Atomic Radiation Speeds Mutations

In Britain and a few other countries where atomics are not only a science but an industry, new and more powerful radioactive substances are being produced that make this speeding of nature an important factor in the development of new countries.

By subjecting plants to radiation, the frequency of natural mutations can be speeded up many hundreds of times. Though only about one in a thousand of the changes are for the good—as in nature—by careful laboratory work the *good changes* can be selected and a new plant can be bred.

The successes are already impressive. India and Japan have made valuable improvements in wheat and rice plants, using radioactive substances supplied to them by Britain, and sometimes with the help of advice from British laboratories.

The aim is to produce crops that can resist disease, can adapt themselves to climatic conditions alien to them, and can give increased yield.

These experiments are very valuable to Asia where atomically-inspired mutations may well introduce valuable new food plants into the area. Also, new types are being bred that will flourish either in arid soil or under extremely humid conditions.

Already achieved is a *barley that grows on a short stalk,* making it easier to harvest but, much more important, giving it strength to withstand storm conditions. High winds

and heavy rain will not beat the crop to the ground.

An entirely new variety of white mustard has been developed, with a superior yield and a better oil content.

Mutations obtained under conditions of radioactivity have also produced seeds that will mature either earlier or later in the season. Experiments now indicate the possibilities of breeding entirely new plants, because seeds that cannot naturally be crossed have been found to produce successful hybrid plants *when one or both of them have been irradiated.*

Increasing Fertility of the Soil

In parts of the world where big tracts of land are being reclaimed from desert, swamp, or sea for agriculture, radioactive isotopes are used to control the fertility of the soil. Britain, the biggest exporter of radioactive isotopes, is helping considerably in this problem.

A chemical examination of newly won soil is easy, but it does not necessarily tell the full story.

Phosphates, essential for the growth of crops, can be present in the soil, but they may be "locked" and unavailable to the plant. By putting radioactive substances in the ground, it can be found how much of the phosphate is being taken up by the plants naturally and what chemical treatment is required to make the land fertile.

Because radioactivity can be detected and measured anywhere, a fairly simple examination of a growing plant will tell how much of the radioactive substance has been sucked into it.

In a case like this, a farmer without radioactive isotopes to help him would have to tend his soil on a hit-or-miss basis which might well mean the failure of his crops for a season or more.

The modern method will effectively analyze the soil in a matter of days and indicate what treatment it needs to make it fertile and keep it that way.

In reclaiming deserts, this soil study and the "unlocking" of the essential minerals in the ground is just as important as effective irrigation.

Aid to Pest Control

The control of insects and pests is an essential preliminary to the opening up of new territory anywhere in the world, and work has been done in South East Asia with the use of the comparatively new atomic tools, radioactive isotopes, in the tracing of mosquitoes.

Mosquitoes that have bred in pools treated with some form of radioactivity can be detected wherever they are found—dead or alive. This makes it possible to discover exactly what area of country is affected by a certain stretch of water and the mosquitoes that breed in it. The insects are not killed by the radioactivity but they are so effectively labeled that it is a simple matter to trace their breeding grounds and exterminate them.

Radioactivity from the waste products of an atomic reactor is being used as a direct weapon against other pests.

The screw worm that attacks cattle is being defeated by breeding large numbers of males and irradiating them so heavily that they are no longer fertile. They are then released in the infected area and, because the females produce only one batch of eggs in their lives, the screw worm population falls dramatically.

Beetles that attack timber have been eradicated by means of atomic radiation. Though it requires a very heavy dose of radioactivity to kill the insects themselves, it has been found that a much lower dose can destroy the larvae and consequently bring the infestation to an end. ◄◄◄

REVIEWS

June-July, 1958

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ABSTRACTS

The American Potash Institute issues a regular abstracts service, summarizing important findings on the role of potash in good soil management and balanced soil fertility. These abstracts, issued 6 times a year, are available on request to professional agricultural workers of the U.S. and Canada. The summaries below illustrate the style in which the abstracts are prepared. For this free service, write: Abstracts, 1102 16th St., N. W., Washington 6, D. C.

Fertilizer Recommendations for Fruit

Fertilizer recommendations for fruit crops. Canada Ont. Dept. Agr. Cir. 303, p. 4-11. Aug. 1957.

Specific fertilizer recommendations are given for orchards, vineyards, and small fruit. Fertilizer ratios recommended are: 0-12-24, 6-12-12, 10-10-10, and 10-5-10. Fertilizers for small fruits should contain the sulphate form of K rather than the chloride. This is particularly true for currants and gooseberries, and to a somewhat lesser extent for raspberries. Sulphate of potash singly or in a complete fertilizer is therefore recommended for these fruits.

Anion Interrelations in Potatoes

Gauseman, H. W. and Corbett, E. G.

The other fertilizer nutrients may be important. Me. Agr. Exp. Sta., Maine Farm Res. 5(3)18-21. Oct. 1957

Much work has been done to determine the effect of KCl and K_2SO_4 on potato quality. In general, K_2SO_4 has given potatoes of the most acceptable quality. The exception to this general statement concerns tubers that are to be used for potato chips. It is commonly thought that potatoes grown with K_2SO_4 produce chips that are off color. This problem is still controversial as to whether it is the SO_4 or Cl alone, or whether it is either anion in combination with K that may affect potato quality for the chipping industry. A new approach to this problem was begun 2 years ago. Consideration was given to the effect of SO_4 and Cl on the uptake of P which in turn might be responsible for differences in quality. To begin this study radioactive P (P^{32}) was used. Summarized results indicate that a certain amount of Cl seems necessary for the best uptake of P^{32} after which P^{32} uptake is decreased. On the other hand, SO_4 tended to decrease P^{32} uptake progressively as the additions of SO_4 became larger. This difference between SO_4 and Cl as they affect the uptake of radioactive P offers an interesting approach to potato quality.

A free-advice-seeking woman asked a farmer what would be good to plant in a spot that gets very little rain due to overhanging eaves, has too much late afternoon sun, has clay soil and is on a rocky ledge.

"Lady," he answered, "how about a nice flagpole?"

~

Abraham Lincoln once attended a charity bazaar and tendered a twenty in payment of a bunch of violets. Getting no change he lowered his hand and touched the girl's wrist. "And what may this be?" he asked. "Why that's my wrist," said the girl blushing. "Thanks for telling me," said the President dryly. "With things as high here as they are I thought it might be your ankle."

~

Usher, passing collection plate at church wedding: "Yes, ma'am, it is unusual, but the father of the bride requested it."

~

A Georgia farmer put this sign in front of his watermelon patch:

One watermelon in this patch has been poisoned.

Next morning the sign had been changed to read:

Two watermelons in this patch has been poisoned.

~

A woman is young until she takes more interest in the fit of her shoes than in the fit of her sweater.

~

The man who wrote and asked if a certain hotel permitted dogs received this answer from the manager: "I've been in the hotel business over 30 years. Never yet have I called the police to eject a disorderly dog in the small hours of the night. Never yet has a dog set the bed clothes afire by smoking a cigarette. I've never found a towel or blanket in a dog's suitcase nor a whiskey ring on the bureau top from a dog's bottle. Sure, the dog's welcome. P. S. If he'll vouch for you, come along too."

~

He: "Let's play Post Office."

She: "Let's play Building and Loan."

He: "What's that?"

She: "You leave the building and leave me alone."

Cauliflower: left, boron treated; right, brown curd with boron deficiency
Alfalfa yellows and rosetting due to boron deficiency
Apples with external cork cracks, necrotic areas and dwarfed
Tobacco with die-back of terminal bud rolling of upper leaves

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